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DEPARTMENT OF THE INTERIOR
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UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 707

GUIDEBOOK
OF THE
WESTERN UNITED STATES

PART E. THE DENVER & RIO GRANDE WESTERN ROUTE

BY

MARIUS R. CAMPBELL

WASHINGTON
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1922

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Principal Divisions of Geologic Time.[a]

Era.	Period.	Epoch.	Characteristic life.	Duration, according to various estimates.
				Millions of years.
Cenozoic (recent life).	Quaternary.	Recent. Pleistocene (Great Ice Age).	"Age of man." Animals and plants of modern types.	1 to 5.
	Tertiary.	Pliocene. Miocene. Oligocene. Eocene.	"Age of mammals." Possible first appearance of man. Rise and development of highest orders of plants.	
Mesozoic (intermediate life).	Cretaceous.	(b)	"Age of reptiles." Rise and culmination of huge land reptiles (dinosaurs), of shellfish with complexly partitioned coiled shells (ammonites), and of great flying reptiles. First appearance of birds and mammals (in Jurassic); of cycads, an order of palmlike plants (in Triassic); and of angiospermous plants, among which are palms and hardwood trees (in Cretaceous).	4 to 10.
	Jurassic.	(b)		
	Triassic.	(b)		
Paleozoic (old life).	Carboniferous.	Permian. Pennsylvanian. Mississippian.	"Age of amphibians." Dominance of club mosses (lycopods) and plants of horsetail and fern types. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals (land vertebrates). Insects. Animals with nautilus-like coiled shells (ammonites) and sharks abundant.	17 to 25.
	Devonian.	(b)	"Age of fishes." Shellfish (mollusks) also abundant. Rise of amphibians and land plants.	
	Silurian.	(b)	Shell-forming sea animals dominant, especially those related to the nautilus (cephalopods). Rise and culmination of the marine animals sometimes known as sea lilies (crinoids) and of giant scorpionlike crustaceans (eurypterids). Rise of fishes and of reef-building corals.	
	Ordovician.	(b)	Shell-forming sea animals, especially cephalopods and mollusk-like brachiopods, abundant. Culmination of the buglike marine crustaceans known as trilobites. First trace of insect life.	
	Cambrian.	(b)	Trilobites and brachiopods most characteristic animals. Seaweeds (algae) abundant. No trace of land animals found.	
Proterozoic (primordial life).	Algonkian.	(b)	First life that has left distinct record. Crustaceans, brachiopods, and seaweeds.	
	Archean.	Crystalline rocks.	No fossils found.	50+.

[a] The geologic record consists mainly of sedimentary beds—beds deposited in water. Over large areas long periods of uplift and erosion intervened between periods of deposition. Every such interruption in deposition in any area produces there what geologists term an unconformity. Many of the time divisions shown above are separated by such unconformities—that is, the dividing lines in the table represent local or widespread uplifts or depressions of the earth's surface.

[b] Epoch names omitted; in less common use than those given.

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PREFACE.

By GEORGE OTIS SMITH.

The United States of America comprise an area so vast in extent and so diverse in natural features as well as in characters due to human agency that the American citizen who knows thoroughly his own country must have traveled widely and observed wisely. To "know America first" is a patriotic obligation, but to meet this obligation the railroad traveler needs to have his eyes directed toward the more important or essential things within his field of vision and then to have much that he sees explained by what is unseen in the swift passage of the train. Indeed, many things that attract his attention are inexplicable except as the story of the past is available to enable him to interpret the present. Herein lie the value and the charm of history, whether human or geologic.

The present stimulus given to travel in the home country will encourage many thousands of Americans to study geography at first hand. To make this study most profitable the traveler needs a handbook that will answer the questions that come to his mind so readily along the way. Furthermore, the aim of such a guide should be to stimulate the eye in the selection of the essentials in the scene that so rapidly unfolds itself in the crossing of the continent. In recognition of the opportunity to render service of this kind to an unusually large number of American citizens, as well as to visitors from other countries, the United States Geological Survey has published a series of guidebooks[1] covering four of the older railroad routes west of the Mississippi. The present volume is an addition to this series and covers one of the finest scenic routes of the continent.

These books are educational in purpose, but the method adopted is to entertain the traveler by making more interesting what he sees from the car window. The plan of the series is to present authoritative information that may enable the reader to realize adequately the

[1] Guidebook of the western United States: Part A, The Northern Pacific Route, with a side trip to Yellowstone Park (Bulletin 611); Part B, The Overland Route, with a side trip to Yellowstone Park (Bulletin 612); Part C, The Santa Fe Route, with a side trip to the Grand Canyon of the Colorado (Bulletin 613); Part D, The Shasta Route and Coast Line (Bulletin 614). These bulletins are for sale by the Superintendent of Documents, Washington, D. C., at 50 cents a copy.

scenic and material resources of the region he is traversing, to comprehend correctly the basis of its development, and above all to appreciate keenly the real value of the country he looks out upon, not as so many square miles of territory represented on the map in a railroad folder by meaningless spaces, but rather as land—real estate, if you please—varying widely in present appearance because differing largely in its history, and characterized by even greater variation in values because possessing diversified natural resources. One region may be such as to afford a livelihood for only a pastoral people; another may present opportunity for intensive agriculture; still another may contain hidden stores of mineral wealth that may attract large industrial development; and, taken together, these varied resources afford the promise of long-continued prosperity for this or that State.

Items of interest in civic development or references to significant epochs in the record of discovery and settlement may be interspersed with explanations of mountain and valley or statements of geologic history. In a broad way the story of the West is a unit, and every chapter should be told in order to meet fully the needs of the tourist who aims to understand all that he sees. To such a traveler-reader this series of guidebooks is addressed.

To this interpretation of our own country the United States Geological Survey brings the accumulated data of decades of pioneering investigation, and the present contribution is only one type of return to the public which has supported this scientific work under the Federal Government—a by-product of research.

In the preparation of the description of the country traversed by the Denver & Rio Grande Western Route the geographic and geologic information already published as well as unpublished material in the possession of the Geological Survey has been utilized, but to supplement this material Mr. Campbell made a field examination of the entire route in 1915–1916. Information has been furnished by others, to whom credit is given in the text. Cooperation has been rendered by the United States Forest Service and the United States Reclamation Service, railroad officials and other citizens have generally given their aid, and other members of the Survey have freely cooperated in the work. For the purpose of furnishing the traveler with a graphic presentation of each part of his route, the accompanying maps, 10 sheets in all, have been prepared, with a degree of accuracy probably never before attained in a guidebook and their arrangement has been planned to meet the convenience of the reader. The special topographic surveys necessary to complete these maps of the route were made by W. O. Tufts.

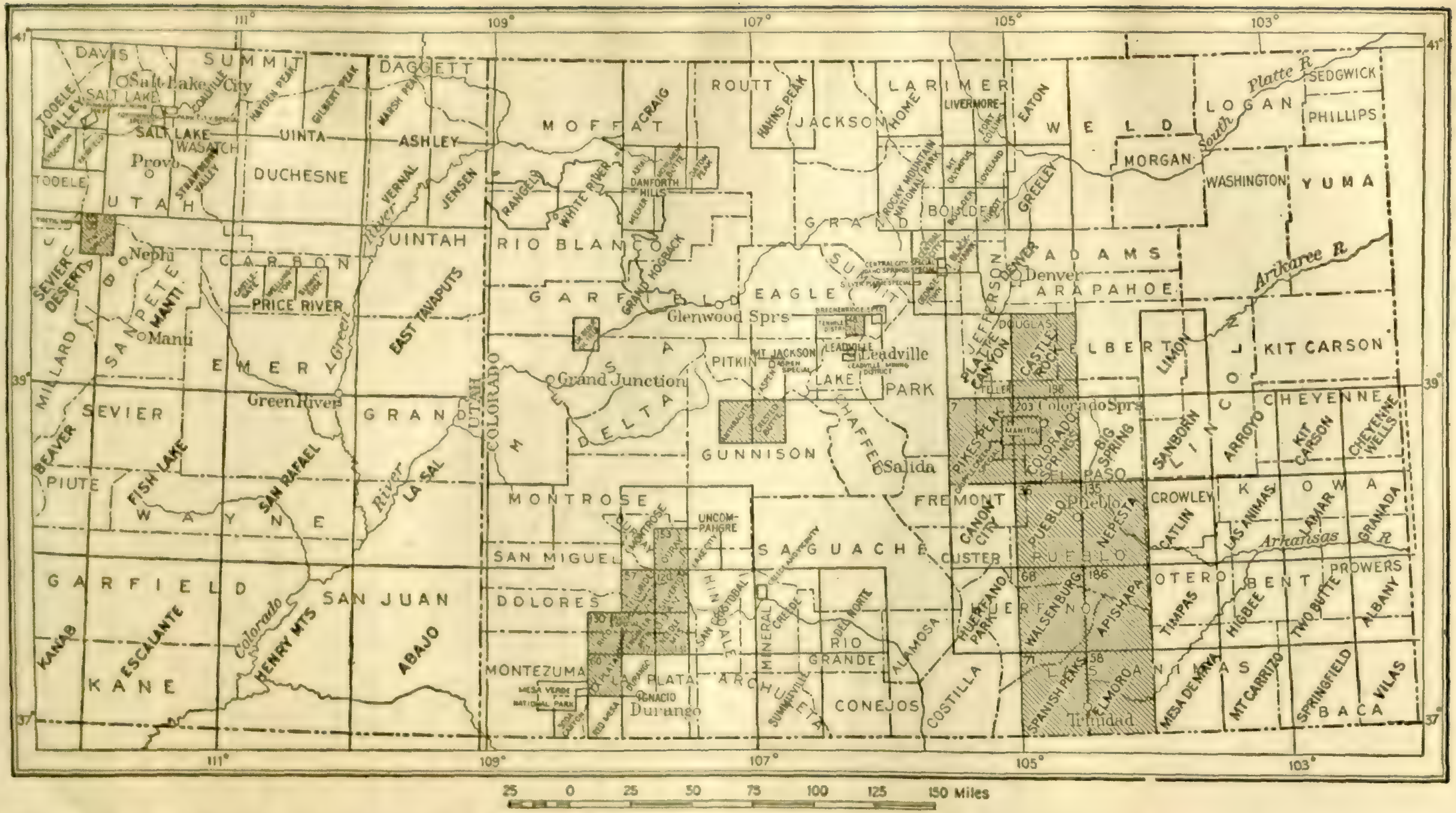


FIGURE 1.—Map of Colorado and part of Utah showing areas covered by United States Geological Survey topographic maps and geologic folios. The quadrangular or irregular areas marked in heavy gothic letters have been mapped, and the areas indicated by diagonal shading and numbers have also been described in geologic folios.

GUIDEBOOK OF THE WESTERN UNITED STATES.

PART E. THE DENVER & RIO GRANDE WESTERN ROUTE.

By MARIUS R. CAMPBELL.

INTRODUCTION.

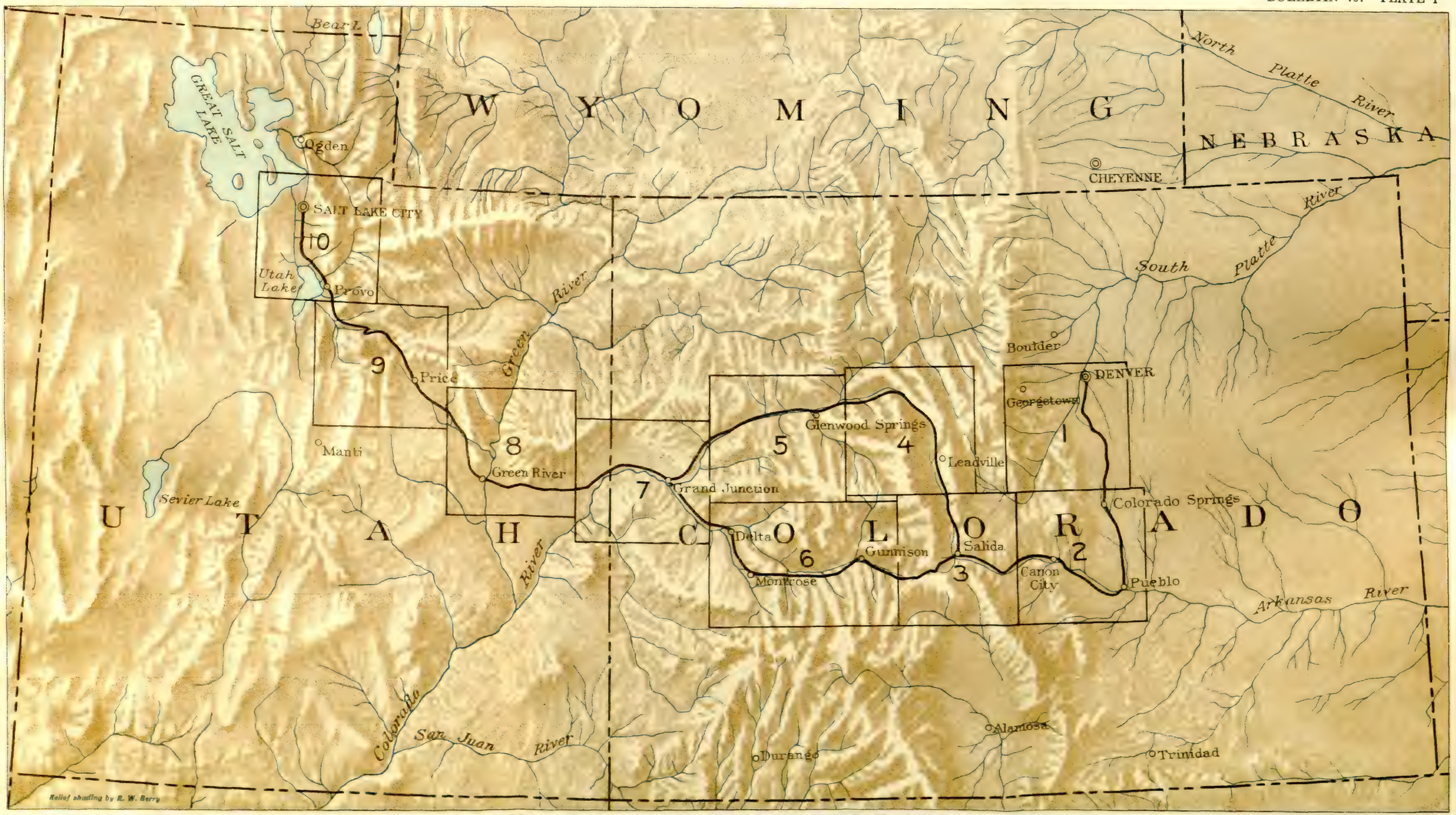
The traveler who crosses the United States from east to west passes over many belts of country, which are different in types of surface features, such as plains, plateaus, and mountains; in climate, especially in amount of rainfall; and in the occupations of the inhabitants, which are largely determined by their environment. He is likely to be more or less familiar with the eastern part of the country, which will therefore not be described here, but as soon as he crosses Missouri River, either at Kansas City or at Omaha, he enters a region that may be to him almost entirely unknown. In this region he grows accustomed rather slowly to the sight of the level, unbroken stretches of the vast plains that extend from Missouri River to the foot of the Rocky Mountains, but at last he becomes reconciled to the treeless landscape and begins to enjoy the freedom of the apparently boundless plain below and the limitless expanse of sky above. He may have expected to see traces of what was once called "The Great American Desert," but the region so named was long ago proved to be a desert only in the imagination of some of the early explorers. As he goes westward, however, he observes that the crops decrease in abundance and that the density of the population decreases correspondingly, but that the country is nowhere free from signs of habitation. In years of drought the plains become parched and brown, but even then they do not resemble the true deserts that lie west of the Rocky Mountains.

In Denver the traveler is still on the plains, but he is so close to their western edge and so near to the commanding peaks of the Rocky Mountains that he naturally regards Denver as a mountain city. He should rather regard it as the gateway to the mountains, for he will find that it is the natural entrance to much of this interesting region and that it enjoys the advantages of both the agricultural resources and transportation facilities of the plains and the mineral wealth and scenic beauty of the mountains.

The great sprawling ranges of the "Rockies" west of Denver constitute one of the most formidable barriers to travel between the East and the West. These mountains extend from the Arctic Circle across Canada and the United States as far south as Santa Fe. In the latitude of Denver the mountainous belt is only about 80 miles wide, but the ranges are rugged and the principal peaks are high, some of them rising more than 14,000 feet above sea level. Mountains of this height that can be seen from the level of the sea are very imposing, but these mountains stand upon a broad platform that is itself 6,000 to 10,000 feet high, and they are consequently less impressive. for their height above their bases is scarcely more than a mile.

The route of the Denver & Rio Grande Western Railroad across the mountains of Colorado and the plateaus and deserts of Utah, shown in Plate I, is particularly noted for the variety of its scenery, as it traverses a region that presents an almost bewildering display of nature's handiwork. In this display the canyons cut by the streams and now followed by the railroad are perhaps the most wonderful features, for they give a very vivid impression of the great activity of the processes going on around us all the time and of the vast amount of excavation that has been done by the streams. Mining is the principal industry in the mountains, and in his journey westward from Denver the traveler has opportunity to see or to visit some of the best-known mining camps in this country. Many of these camps are of recent development, but some date back to the time when gold was first discovered in the West, and about them still cling the glamour and the romance of that time, when law was unknown and fortunes were made or lost in a single day.

West of the Rocky Mountains, extending to the west face of the Wasatch Range, lies what is generally known as the Plateau Province, called by Powell the "Canyon Lands"—a region of high plateaus and deep canyons, which in this respect has no peer in the world. In this region there are few mountain peaks, and the prevailing type of upland is the plateau with nearly level top and steep or even vertical sides. The slopes in these dry lands are generally angular; they have not the smooth, flowing curves of those in more humid regions. In the plateaus streams have carved deep canyons, the most remarkable of which, the Grand Canyon of the Colorado, reaches in its deepest part a depth of 6,000 feet. The entire surface of the country is so intricately seamed with canyons that it can be crossed only at certain places and even there only with great difficulty. The precipitation in the region is very small, probably not more than 5 or 6 inches in a year on the lower lands, so that these lands are veritable deserts. They can be successfully cultivated by irrigation, however, and much money has been spent



RELIEF MAP OF COLORADO AND UTAH

Showing main lines of the Denver & Rio Grande Western Railroad and areas covered by sheets of route map

50 0 50 100 150 Miles

by private irrigators and irrigation companies and by the Government in carrying the waters of the rivers onto the thirsty land. The climate at the lower levels is generally mild, and where the lands have been thus watered crops of various kinds, including fruits, are raised in abundance. Agriculture and coal mining are the principal industries, but they are restricted to certain tracts near the railroads.

Beyond the Wasatch Mountains lies what is known as the Great Basin, which stretches westward from them farther than the eye can see. This is really an immense surface basin, rimmed about by higher land that prevents the streams within it from reaching the ocean. If the rainfall were heavy the streams would find outlets, but as it is only a few inches a year the evaporation equals the rainfall and the region is a desert; so little water is available that enough can not be had for irrigation except near its margin and in small areas where the conditions are exceptional. Near the border of the basin there are a few fresh-water lakes, but most of the lakes within it are salty, like Great Salt Lake, which the traveler will see at the western terminus of the Denver & Rio Grande Western Railroad. In the interior of the Great Basin there were once many lakes, but they dried up ages ago, leaving their bottoms snow-white with deposits of soda, borax, and common salt. The principal occupation in this region is metal mining, and the mines are in the isolated mountain ranges that corrugate the floor of the basin and break the monotony of its surface.

West of the Great Basin are the Sierra Nevada and the great interior valley and coastal features of California.

DENVER, COLO.

The traveler who is unfamiliar with the West will find much to interest him in and about Denver. The city has sprung up in a short time; it is, indeed, but little more than 50 years old. Its population, according to the census of 1920, was 256,491. The traveler who may have thought of Denver as a city in the center of a great mountainous empire may be disappointed in finding, when he arrives there, that it is a city on the plains, 15 or 16 miles east of the foothills and 50 to 60 miles east of the Continental Divide, or the main crest of the Rocky Mountains. (See Route map, sheet 1, p. 32.)

Although it is on the plains, Denver, in common with many towns in and near the mountains, owes its first settlement to the discovery of gold, which was found in the sand of Cherry Creek by a band of prospectors who were bound to the mountain region. The sand was not commercially productive, but the camp established for the purpose of working it has grown and is to-day a fine city with

broad streets, great manufacturing plants, large stores, numerous business blocks, commodious hotels and residences, and beautiful boulevards and parks.

The exploration that led to the founding of the city of Denver, like those that led to the founding of many other cities, is shrouded more or less in mystery. Gold was certainly the lure that brought the explorers here, but when and where gold was first discovered in what is now Colorado are not certainly known. There are many legends that the precious metal was found in the foothills and the mountains of Colorado prior to 1850, but most of these legends are vague and unreliable. What appears to be the first authentic account of an exploration in this vicinity is a story that a party of Cherokee Indians, in the spring of 1849, went to the Pacific coast by way of the old trail up the Arkansas Valley across the Squirrel Creek divide (just east of Palmer Lake), and down Cherry Creek to the South Platte at the site of the present city of Denver. The story goes that the Indians found some gold in the Rocky Mountains but not enough to deter them from continuing their trip to California. When they reached the coast they did not find gold as abundantly as they had expected, so they returned to Georgia fully convinced that there were opportunities in the Rocky Mountains just as promising as they had seen in California.

In 1858 the Cherokees again organized a gold-seeking expedition, which was joined by many white men. This party, which was known as the Green Russell party, went to Cherry Creek, where the Indians had found some gold on their previous visit. They prospected along Cherry Creek and South Platte River, and many people flocked to their camp. Little gold was found, but the camp persisted, and several settlements sprang up on or near the site later occupied by the city of Denver. The first town established in this vicinity was on South Platte River 6 miles above the mouth of Cherry Creek. It was called Montana and consisted of about twenty log cabins, but it did not survive a year. The first town on the actual site of Denver was called St. Charles. It was organized September 24, 1858, and, like most towns of this period, it existed at first only on paper; it was not until October that the first structure was erected. This structure consisted of a few logs piled up and surmounted with a wagon cover, and this was probably the first building on the site of Denver. About the middle of October Georgians established a town on the west side of Cherry Creek which they called Auraria, after a small mining town in Georgia.

The town of St. Charles made no progress until the 17th of November, when Gen. William Larimer and Richard E. Whitsett arrived there and rechristened it Denver City, in honor of Gen. J. W. Denver, the governor of the Territory of Kansas, which then in-

cluded that part of the present State of Colorado which lies east of the crest of the Rocky Mountains. The first house in Denver is said to have been erected by Gen. Larimer on the banks of Cherry Creek, between what are now Blake and Wazee streets. The towns of Montana and Auraria soon disappeared or were swallowed up by the more rapidly growing "City of Denver," as it was known in the early days.

Denver, though not a mining city, has long been the financial and distributing center of an immense mining region, including the Rocky Mountains from northern Wyoming to southern New Mexico. It has become also a great railroad center, partly because it is a center of distribution and partly because most tourists making a trip to the Far West desire to pass through or stop in this flourishing city. The city has the wonderful health-giving climate of the mountain region, and many who have found the humid, heavy atmosphere of the East depressing have each year sought and been benefited by the dry, exhilarating, and rarefied air of Colorado.

Denver is now the metropolis of the Rocky Mountain region. It is noted for its broad, clean streets, its handsome residences, and the beauty and number of its public parks. Grass and trees are not natural to Denver, so the people there take the greatest interest in them and are willing to spend time and money freely for a beautiful lawn and a growth of trees. Farther east, where such things are abundant, they are not prized so highly and are generally neglected, so that they do not grow in the perfection that they attain in the semiarid region, where irrigation is possible.

One of the best known of Denver's parks is the Capitol Grounds and Civic Center, shown in part in Plate II. The Civic Center has recently been acquired by the city and made into a beautiful park. The largest of Denver's playgrounds is City Park, which contains 320 acres and has been beautified by trees, flowers, lakes, and fountains until it is the equal of almost any other artificial park in the country. In it is a zoological garden and a museum of natural history. Washington Park also is becoming one of the beauty spots of the city. Cheesman Park is noted for the magnificent view of the mountains which may be had from its pavilion. Here on a clear day the traveler may obtain a sweeping view of the great Front Range from Longs Peak, 60 miles away on the north, to Pikes Peak, 80 miles to the southwest. To assist the traveler to recognize the more prominent peaks a brass plate, upon which are engraved the names of the peaks and the lines of sight pointing toward them, has there been set on a pedestal. This diagram, together with a fairly good map of the State, enables one to place accurately all the more striking mountain features in the vicinity.

Another excellent vantage point from which to view the mountains is the dome of the Capitol (Pl. II). This fine building, which is constructed of native granite and marble, stands on a commanding terrace facing the west. The dome is 276 feet high, and from its balcony on a clear day a vast extent of the mountain front may be seen.

Fronting the Capitol is the Public Library and the United States Mint, both constructed of Colorado granite and both massive buildings, which serve as a fitting setting for the State Capitol. The library is interesting as a piece of Grecian architecture and the mint as the place of manufacture and the storage of vast sums of Government coin. The new Federal post office, a beautiful building, which occupies an entire city block, is built of Colorado marble. This stone is just becoming well known and is being used in many parts of the country, notably in the new Lincoln Memorial in Washington, D. C. It is taken from quarries about 40 miles south of Glenwood Springs. Another public building that attracts attention is the great auditorium, built to accommodate the Democratic national convention of 1908. It seats 12,000 persons and contains one of the finest theaters in the United States, seating 3,500 persons.

Denver is an active industrial city, and its manufacturing plants make many and various articles ranging from railroad cars to radium salts. Perhaps the most interesting plant to the average traveler is the smelter for the reduction of the ores of the precious metals. A description of a smelter is given on pages 252–254. There are also brick and clay works, railroad shops, and other works.

Denver is noted for the excellence of its public schools and for the beauty and serviceableness of its school buildings. It is a center of higher education also, for the State University is at Boulder, less than 20 miles northwest of the city; the State School of Mines is at Golden, 16 miles west of it; and Denver University is in the city.

The residential part of the city is very attractive. The houses are substantial and are surrounded by velvety lawns diversified and beautified by flowers and shrubs. No frame buildings can be erected within the city limits.

Although the extremes of temperature at Denver are rather great, the summer temperatures reaching 95° F. or more and winter temperatures touching the zero point, the climate is not hard to bear, for the air is so dry that the extremes of either summer or winter are not felt as they are in a more humid climate. According to seven years' records of the Weather Bureau the mean annual precipitation is 13.7 inches and the mean annual temperature is 50°. The dryness of the air may be better appreciated by comparing it with that of

STATE CAPITOL, DENVER.

This building, of Colorado gray granite, stands on a terrace overlooking the business part of the city and commands a fine view of the far-away mountains. It is surrounded by a wide stretch of lawn that includes the Civic Center and the grounds of the public library. Photograph by L. C. McClure, Denver.

A. WHEAT FIELD IN CLEAR CREEK VALLEY.

Water has transformed Clear Creek valley from a barren waste to rich agricultural land. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.

B. MOUNTAIN FRONT ON THE "MOFFAT ROAD."

The Denver & Salt Lake Railroad, in climbing the steep mountain front, tunnels through great slabs of dark-red sandstone upturned against the mountains. Between tunnels the traveler may obtain views of the plains stretching away to the east, farther than the eye can see, and of the low ridges that skirt the mountain at his feet. Photograph copyrighted by L. C. McClure, Denver; furnished by the Denver & Salt Lake Railroad.

the Atlantic coast, where the mean annual precipitation is 45 to 50 inches.

The description of the scenery along the line of the Denver & Rio Grande Western Railroad begins on page 22.

ONE-DAY TRIPS FROM DENVER.

As most of the westbound travelers who pass through Denver stop over a few hours or a few days, it is desirable to call their attention to many side trips that may be made in one day by trolley, railroad train, or automobile.

Most people are attracted by the mountains, and the excursions that are generally of the greatest interest are those made into their narrow canyons or over their snowy summits. Not only are the mountain trips enjoyable on account of the scenery, but they enable the traveler to have the pleasure of tramping over snow banks under the hot rays of a midsummer sun, to see something of the mines of gold and silver and other metals that have made this region famous, and to behold the magnificent exposures of rock along the canyon walls and in the highest peaks and thus to learn some of nature's hidden mysteries regarding the earth upon which he lives.

CONTINENTAL DIVIDE AT CORONA IN ROLLINS PASS.

Corona is reached by the Denver & Salt Lake Railroad, or "Moffat road," as it is generally called. It is the objective point of most travelers who wish to enjoy the pleasure of snowballing on a hot summer day and of experiencing the sensation of standing on the backbone of the continent. On leaving Denver for this trip the traveler sees first the fine irrigated farms of Clear Creek valley (see Pl. III, *A*) and then the upturned beds of sandstone and shale which carry the coal of the Denver Basin. These rocks, which are called by geologists the Laramie formation, are of Cretaceous age, and their position in the geologic column is shown on page 11. No coal beds can be seen from this railroad, but a few miles to the north there are extensive mines.[1]

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[1] Coal has been mined in Colorado continuously since 1864, 12 years before the Territory became a State. One of the first fields to be developed was that of Boulder County, which lies in the northern part of what geologists call the Denver Basin. This basin, though not a surface basin, is so called because the beds of rock in it dip toward and under the city from all directions, so that any one bed of rock, if it could be followed below the surface, would be found to have the form of an irregular basin. The western rim of the basin is formed of the rock beds that are upturned along the mountain front in the vicinity of Morrison, Golden, and Boulder, but the eastern rim is not conspicuous, as the beds dip very gently westward toward the center of the basin.

The coal is contained in sandstone and shale of Cretaceous age (Laramie formation) and probably underlies

At the loop which the railroad makes before it climbs the eastern front of the mountains there is exposed a dark shale (Benton shale or lower part of the Colorado group), which lies near the base of the Upper Cretaceous series. At Plainview the road cuts through a hogback[2] formed of the upturned edge of the underlying Dakota sandstone and shows some of the variegated sandstone and shale of the Morrison formation, which lies directly below the Dakota sand-

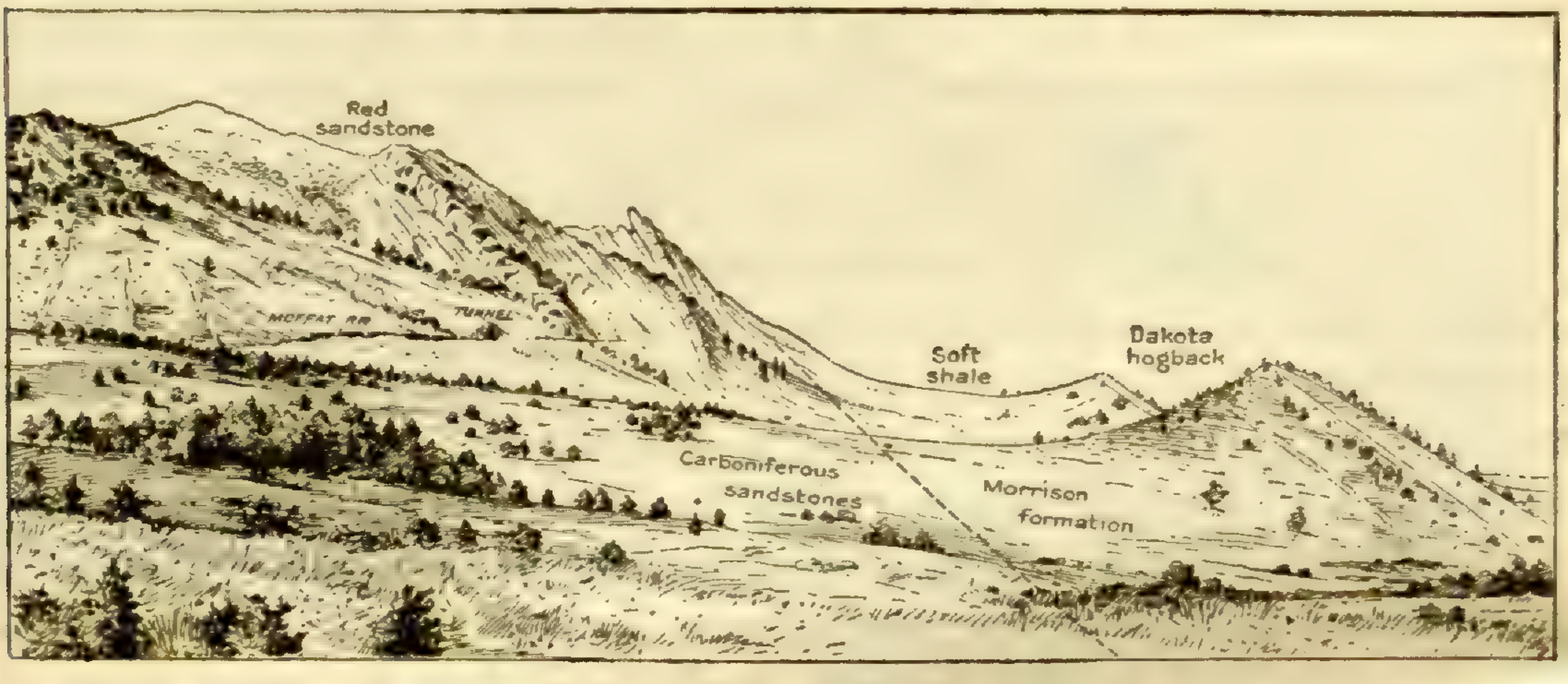

FIGURE 2.—Dakota hogback and mountain front north of Plainview, as seen from the "Moffat road." The dash line indicates the boundary between the Morrison formation and the Carboniferous sandstone.

stone, or toward the mountains. The succession of rocks in the hogback and the mountain front is shown in figure 2. Beyond the valley formed in the soft rocks of the Morrison formation the red sandstone (Fountain formation) lies upturned against the mountain front in great triangular slabs like the teeth of a gigantic saw. (See Pl. III, *B*.) The railroad in climbing the mountain front pierces the projecting points of this hard layer by many short tun-

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Denver itself, but here it is so far below the surface that it has been reached in only the deepest drillings. The coal is mined from slopes which go down on the outcrop of the coal bed or from shafts which are sunk nearer the center of the basin and which reach the coal at different depths.

The coal is what is now generally called subbituminous, a rank which is below that of the bituminous coals of the East. It is frequently called "black lignite," because of its color and because it has some of the properties of a lignite, or woody coal. The subbituminous coal does not soil the hands and is a desirable domestic fuel, but upon exposure to the weather it breaks up or "slacks"—the lumps fall to pieces and the coal becomes a heap of fine fragments. It contains a much higher percentage of water than the eastern coals, and this gives it a much lower fuel value. Notwithstanding these defects, subbituminous coal is extensively mined and finds a ready market throughout the Denver region.

[2] A name applied in the Rocky Mountain region to a sharp-crested ridge formed by a hard bed of rock that dips rather steeply downward. One of the best examples of this kind of surface feature can be seen at Canon City, where the Skyline Drive follows the sharp crest of a hogback of Dakota sandstone for miles, as shown in Pl. XXXV (p. 73).

nels, and the traveler has ample opportunity to study its characteristics as the train turns and twists around the ravines or dives headlong through the rocky tunnels. (See Pl. IV, *A*). This red sandstone is tilted up against the gneiss (pronounced *nīce*) or granite-like rock that forms the bulk of the Front Range.

When these beds of sandstone were formed they consisted of horizontal layers of sand, which were laid down along the shore of a body of water, just as sand accumulates to-day along the shore of the ocean or of a large lake. The rocks upon which the sand rested were granite and gneiss, from which some of it was derived, and the sand lapped onto the shore irregularly, some beds extending much farther inland than others, the distance inland reached by them at one place or another depending on the form of the surface and the height of the water. Finally, after the entire region had been cov-

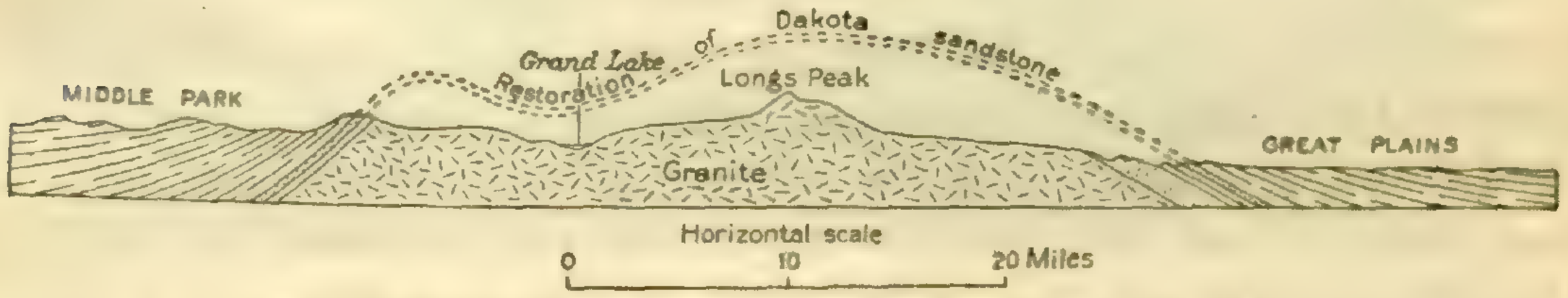

FIGURE 3.—Arch of the Front Range restored. After Lee.

ered by layers that eventually became sandstone, shale, and limestone, the region on the west was lifted up hundreds or perhaps thousands of feet, and the red sand, which had hardened into sandstone, was bent upward in a great arch that may have extended entirely over the present Front Range. The streams probably cut away the upper part of this arch almost as fast as the land was raised, so that the mountains may never have been much higher than they are to-day. The work of the streams has been continued until all of the upper part of the sandstone arch has been removed, as shown in figure 3, and only the sharp upturn on the flanks, which can be seen so well from the "Moffat road," has been preserved.

The train climbs steadily, affording here and there beautiful views far out over the plains to the east, and finally, when nearly above Eldorado Springs, it turns suddenly to the left and enters a tunnel that leads through the heart of the mountains. Beyond this tunnel the roadbed is in granite,[3] and the banding of this rock gives little

[3] Wherever the crystalline rocks of the mountains are referred to in this guide they are called granite, though they really consist of granite, gneiss, and schist. In some places the rock may be entirely granite, and in others it may be gneiss or schist; but at many places these three kinds of rock are intimately mixed, showing that they may be different forms of the same rock.

G. P. Merrill describes gneiss (A treatise on rocks, rock weathering, and soils, pp. 142–145, New York, 1906) as follows:

"The composition of the gneisses is essentially the same as that of the granites, from which they differ

indication of the real structure of the mountain range. The streams have cut deep canyons, and many interesting views may be seen on the right of the train as it passes from branch to branch of South Boulder Creek, here crossing a canyon on a high trestle and there plunging into the darkness of a tunnel through a spur. Where South Boulder Creek is first seen it lies far below the level of the road, but its bed slopes steeply headward and is finally crossed by the railroad well above the sharp canyon, which represents the latest period of stream cutting in this region. If the trip is made in July the traveler may have the pleasure of seeing in the foothills acres of the beautiful Rocky Mountain columbine (Pl. IV, *B*), which has been adopted as the floral emblem of Colorado. The plant grows about 3 feet high, and each stalk bears a number of delicate lavender-tinted blossoms which become white as the season advances.

The first large village above the point where the railroad crosses South Boulder Creek is Rollinsville. Here the traveler sees no suggestions of mining, but if he could follow for a distance of 4 miles the road that climbs the hill on the north (right) he would find himself in a district that furnishes the metal for the filaments of most of the incandescent electric bulbs made in this country. This metal is tungsten, and a small percentage of it is contained in the steel from which most of the modern machine tools are made.

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only in structure and origin. * * * Structurally the gneisses are holocrystalline [entirely crystalline] granular rocks, as are the granites, but differ in that the various constituents are arranged in approximately parallel bands or layers. * * *

"In width and texture these bands vary indefinitely. It is common to find bands of coarsely crystalline quartz several inches in width, alternating with others of feldspar, or feldspar, quartz, and mica, or hornblende. A lenticular structure is common, produced by lens-shaped aggregates of quartz or feldspar, about and around which are bent the hornblende or mica laminae [layers]. The rocks vary from finely and evenly fissile through all grades of coarseness and become at times so massive as to be indistinguishable in the hand specimens from granites. * * *

"The origin of gneisses * * * is in many cases somewhat obscure, the banded or foliated structure being considered by some as representing the original bedding of the sediments, the different bands representing layers of varying composition. This structure is now, however, considered to be due to mechanical causes and in no way dependent upon original stratification. The name, as commonly used, is made to include rocks of widely different structure, which are beyond doubt in part sedimentary and in part eruptive but in all cases altered from their original conditions.

"This alteration * * * has been brought about not by heat and crystallization alone, but in many cases by processes of squeezing, crumpling, and folding so complex as almost to warrant the application of the term kneading. * * *

"In the present state of our knowledge it is in most cases impossible to separate what may be true metamorphosed sedimentary gneisses from those in which the foliated or banded structure is in no way connected with bedding and which may or may not be altered eruptives."

A. TUNNELS ON THE "MOFFAT ROAD."

Tunnel succeeds tunnel in rapid succession on this railroad as it climbs the Front Range above Plainview. Photograph by L. C. McClure, Denver; furnished by the Denver & Salt Lake Railroad.

B. STATE FLOWER OF COLORADO.

The Rocky Mountain columbine (Aquilegia coerulea) covers in midsummer many of the mountain slopes with its beautiful bloom. At first the outer petals are a delicate lavender or blue, but they soon fade to the purest white. Photograph furnished by the Denver & Rio Grande Western Railroad.

JAMES PEAK.

This peak (13,260 feet) is one of the high points of the Continental Divide, a few miles south of Corona. The proposed tunnel of the "Moffat road" is to pass under it. Note the great amphitheater (cirque) which an ancient glacier has cut in the foreground on the right, and also the plateau-like character of the summit as shown in the distance. Photograph copyrighted by L. C. McClure, Denver; furnished by the Denver & Salt Lake Railroad.

A few miles below Tolland the valley changes from a rocky V-shaped ravine to a broad valley having a U-shaped cross section. The meaning of such a change is shown in figure 4. The mountain valley shown in figure 4, *A*, has been carved only by the stream which occupies it. The walls slope gradually from the ridge on either side to the stream in its bottom, and the form of a section of such a valley, if cut directly across, would be a flat V. If after its excavation by the stream this same valley had been occupied by a glacier the ice would have ground away the projecting spurs on its sides and left it in the form shown in figure 4, *B*. The cross section of a valley is a nearly infallible indication whether the valley has been carved by running water alone or has been modified by ice. Thus the change from a V shape to a U shape a few miles below Tolland marks the point of farthest extension of the old glacier that had its source near the summit of James Peak and filled this valley with ice to a depth

FIGURE 4.—Diagrams showing effect of stream and glacial erosion. A, V-shaped valley cut by running water; B, same valley after it has been occupied by a glacier and reduced to a broad, flat U in cross section.

of many hundreds of feet if not a thousand feet. Usually the foot of a glacier of this magnitude is marked by a terminal moraine—a ridge of loose material carried down by the ice—but if such a moraine was ever built in this locality it has been washed away by the stream swollen with the waters of the melting ice.

Although the valley at Tolland and for some distance above that place is broad and the slopes are smooth, it soon terminates abruptly at the foot of the Continental Divide, and no railroad can ascend it much farther and succeed in crossing the range. Consequently the engineers were forced to turn aside from what seems to be an easy pathway up the valley and construct the road to the summit in a roundabout way by scaling the valley walls. The train makes this climb with many turns and twists, and the traveler is generally deeply impressed with the care and precision with which the engineers fitted the roadbed to the mountain slopes. To the railroad engineer no slopes are too steep for railroad construction, provided he can find ground sufficiently level to enable the road to curve

around and double back upon itself, thus zigzagging its way up the mountain slope. The train climbs steadily upward, and one by one the ridges that from below seemed to be of great height are surmounted and they are found to be only low spurs of the still higher mountains above.

As the train nears the summit and encircles the little pond called Yankee Doodle Lake, the traveler may see some of the effects, other than the rounding of valleys, that the old glaciers have produced on the mountain scenery. In the canyons below, where the ice moved down in a great stream from the heights above, its effect was to smooth and round the slopes and to do away with much of the ruggedness that must have marked these canyons before they were occupied by the ice. Near the summit the ice scooped out in the side of the mountain great amphitheaters, called cirques, making the tops much more rugged than they were before. The circular depression that holds Yankee Doodle Lake is such a cirque, and all the vast rock slopes above the lake have been steepened by undercutting by the ice. Other cirques (such as those shown in Pl. V) may be seen in the mountains; indeed, the entire front above this place, up which the railroad finds its way to the summit, consists of the walls of cirques that have united. The steepness of this slope is due almost entirely to the action of ice. In places the road is constructed along the upper edge of one of these great cirque walls, and the traveler may look down on the right nearly 1,000 feet into the cirque below. Although the cliff has an appreciable slope, it appears to be vertical especially when viewed from the moving train.

At last the traveler reaches the summit, at Corona, 11,680 feet above the level of the sea, but the great snowsheds through which the train passes have prevented him from getting a fair view of the mountain summit. As soon as the train stops at Corona he may pass from the confinement of the snowshed and enjoy to the utmost the boundless space of the mountain top. On the crest in any direction there are peaks higher than Corona, the most prominent being James Peak (13,260 feet) on the south and Longs Peak (14,255 feet) on the north, but they can be seen from only a few points. On the west the traveler can look down on the billowy surface of Middle Park, one of the surface basins in the midst of the mountains; and on the east he can look over the wide expanse of spur and ravine up which the train has so laboriously climbed.

The railroad beyond Corona descends the fairly smooth western slope of the Front Range by many loops and turns until it reaches the floor of Middle Park. It crosses this immense basin in the heart of the mountains, cuts through the Gore or Park Range beyond in a deep, rugged canyon, and then continues westward across the great plateau country of northwestern Colorado. The plateau contains

one of the great coal fields of the State, which has only recently been developed. The coal is better than that of the Denver Basin, and much of it finds a ready market in the towns on the plains between Denver and Omaha.

GEORGETOWN AND MOUNT McCLELLAN.

The journey to Georgetown is made on a narrow-gage line of the Colorado & Southern Railway and is confined entirely to the valley of Clear Creek, which joins South Platte River about 6 miles north of the Union Station in Denver. From Denver to Golden the general course of the road is up the broad, flat valley, which is irrigated by water taken from the creek higher up. This valley is highly cultivated, and many fields of grain (see Pl. III, *A*, p. 7) may be seen from the train. Near the mountains the bottom of the valley is composed largely of gravel and boulders brought down by the creek in times of flood, and crops grown on such soil are scanty even where water for irrigation is abundant.

Just below Golden (named in honor of Tom Golden, one of the pioneers of this region) the valley narrows and is flanked on either side by flat-topped hills, or mesas,[4] as they are generally called in the Southwest, about 400 feet high. These mesas are remnants of a once extensive plain formed at this level by streams that planed off the inequalities of the land. Where the beds of rock are horizontal, as they are about Denver, the surface of the plain corresponds to the bedding of the rocks, but where the rocks are upturned on the flank of the mountain, as they are at Golden, they were planed off just the same. After the streams had reduced the soft rocks to a relatively smooth surface a great flood of lava that was ejected from some vent in the mountains rolled out over the plain and spread for a distance of many miles. When this mass of lava cooled and became consolidated it formed a rock called basalt, which is harder than the soft sandstone and shale upon which it rests, and for that reason it served as a protecting cap when the region was uplifted and streams began to cut the rocks away. Most of the basalt is now gone, and the parts seen from the train are doubtless mere fragments of a once extensive and continuous sheet. The rocks upon which the lava was spread are the Denver and Arapahoe formations, of Tertiary age, and the Laramie formation, of Cretaceous age.

Behind these mesas, which are outliers or foothills of the mountains, is a beautiful valley, which has been eroded in the upturned edges of the softer and lower formations. These rocks can not be seen distinctly from the train, but in near-by localities they are well exposed as they bend upward and rest upon the granite that forms

[4] Flat-topped hills are named mesas because of their resemblance to a table (Spanish mesa, pronounced may'sa).

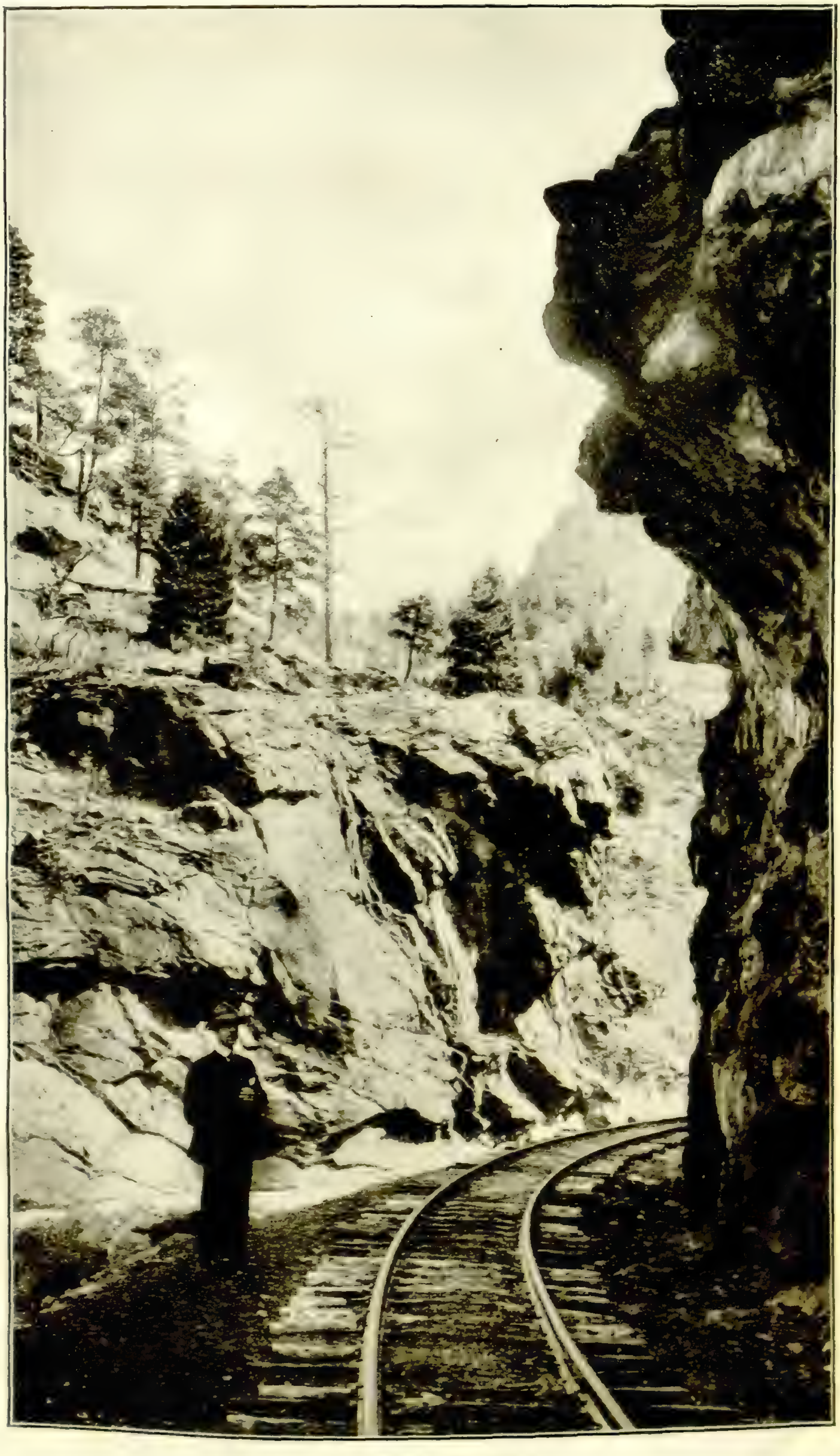
the mountain mass. In this valley is Golden, which for a time was the Territorial capital. Here is the Colorado School of Mines, some of the buildings of which may be seen on the left. Here are also smelters and mills for reducing the ores mined farther up the creek.

Immediately on leaving Golden the train plunges into the narrow, tortuous canyon which Clear Creek has cut into the uplifted granite mass. When boarding the train at Denver the traveler may have wondered why this road was ever built narrow gage (3 feet), or, even if so built, why it was not changed years ago to the standard gage, but when he sees this canyon he no longer questions the wisdom of the builders of the road in adopting the narrow gage nor that of the management in retaining it. He soon realizes that only a single narrow-gage line could have turned and twisted its way through the canyon and that the change to standard gage would mean the building of extensive tunnels and many bridges. The little narrow-gage line, on the contrary, as shown in Plates VI and VII, winds around every bend of the creek and every projecting spur of the mountain and required almost no cutting of the solid rock.

Although the canyon nearly everywhere has precipitous walls, it varies greatly in width. At some places, as shown in Plate VII, it is merely a cleft sufficient to accommodate the stream that carved it; at others it is so broad that the stream has built flood plains upon which the railroad has little difficulty in finding its way. The cutting power of the stream has been nearly uniform throughout, but the resultant form of the canyon depends largely upon the resisting power of the rock through which it has been cut. Thus, where the granite is exceedingly massive—that is, without joints or fissures of any kind to weaken its resistance—the stream has not greatly widened its gorge, but where the rocks are seamed with innumerable joints, or where they have been so much squeezed as to form schists, the stream has cut out a wide canyon.

The rock in which the canyon is cut is generally called granite, but some of it is banded and is properly called gneiss. (See footnote on pp. 9–10.) The bands of the gneiss show great contortions, which are the result of movements in the rocky crust of the earth. The gneiss is also seamed with dikes (rocky material that was once melted in the earth's interior and forced into fissures of the rock) and veins (mineral matter deposited from waters circulating through fissures in the rock) of great variety of color and texture. In places the rocks are nearly black with the mineral called hornblende; in other places they are composed largely of white or pink feldspar or are gray granites.

At Forks Creek the canyon divides, and the railroad branch to the right runs to Central City and Blackhawk, two of the most important and oldest gold-mining centers of Colorado. Central City



"MOTHER GRUNDY."

"Mother Grundy" from her position overlooking Clear Creek keeps a sharp lookout on all travelers. The massive granite and the tortuous stream are well shown in this picture. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.

NARROWS OF CLEAR CREEK CANYON.

In places the gorge is so narrow and the bends are so abrupt that both the stream and the railroad seem to disappear in some rocky cavern, but on rounding the bend they may be seen pursuing their tortuous course hemmed in by vertical or overhanging cliffs several hundred feet high. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.

was built near the spot where, in 1859, John H. Gregory made the second great discovery of gold in this region.[5]

A few miles above Forks Creek the canyon becomes less rugged. The first level bottom land the traveler has seen since leaving Golden is occupied by the town of Idaho Springs (altitude 7,556 feet), which is noted both as a pleasure resort and as a mining center. The waters are mild solutions of carbonate and sulphate of soda and have tem-

[5] This discovery is described as follows by E. S. Bastin:

In romantic interest and as a record of human achievement in the face of great difficulties the story of the discovery and early development of the mineral wealth of this region can hardly be surpassed by any other chapter in the history of the "winning of the West." A decade after the historic "rush" of the forty-niners to California a second great westward movement of gold seekers from the Eastern States was started by the discovery of gold in alluring quantities near the present sites of Idaho Springs and Central City. It was first found in gravel on the outskirts of the town of Idaho Springs by George A. Jackson, early in 1859. A few months later the rich outcroppings of a gold vein were discovered on the present site of Central City by John H. Gregory. These two discoveries precipitated a stampede of prospectors, and within a few weeks many of the richer veins of the region had been discovered and many new deposits of gold-bearing gravel located. This discovery began an era of mining development that led to the foundation and early growth of Denver and of the State of Colorado. Up to the end of the year 1918 there had been added to the world's supply of the precious metal from the counties of Gilpin and Clear Creek alone approximately $175,000,000. Although the period of maximum production was between the years 1870 and 1900, the two counties still produce annually metals to the value of more than $1,000,000.

The gold-bearing gravel was small in quantity and was worked out mainly in the early years of mining. Since then the gold has been taken mainly from veins. Most of the veins are steeply inclined and traverse schist, gneiss, and granite, with which are associated dikes and irregular masses of younger intrusive rocks—the "porphyries" of the miners. The deepest workings are those of the California mine at Central City, whose shaft descends 2,250 feet down a steeply inclined vein. A few of the veins are traceable on the surface continuously for more than a mile, and most of them are between 1 and 5 feet wide. The principal metals won from the ores are gold and silver, but copper, lead, and recently zinc have also been obtained. From a few of the veins near Central City pitchblende or uraninite, one of the minerals from which radium is obtained, has been mined, and this is the only locality in the United States and one of the few in the world at which the mineral is found in commercial quantities.

The ores are believed by geologists to have been deposited by hot solutions given off from buried masses of slowly cooling "porphyry." The hot waters at Idaho Springs have possibly a similar origin, though their mineral content is probably much less than that of the waters which originally brought up the gold and silver from lower levels.

(See Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, 1908; Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colo.: U. S. Geol. Survey Prof. Paper 94, 1917.)

peratures ranging from 75° to 120° F. Hotels and bathhouses make the place very attractive to the traveler who can spend a few days in the bracing atmosphere of this mountain resort.

The first really noteworthy discovery of gold in Colorado is commemorated by a monument at the mouth of Chicago Gulch, a canyon entering that of Clear Creek from the left of the railroad nearly opposite the station at Idaho Springs. This discovery was made by George A. Jackson in January, 1859. When winter was over Jackson returned to the mountains and on May 7 began placer mining on Jackson Bar.

One of the most notable achievements of mining engineering in this region is the Argo (formerly Newhouse) tunnel, whose large waste dumps may be seen in the eastern part of Idaho Springs. This tunnel extends northward for 5 miles to a point beneath the town of Central City. It cuts many of the veins far below the surface, draining the upper workings and facilitating deep mining. Much ore is brought from the Central City district to Idaho Springs through this tunnel, and mining at or below its level has shown that rich gold ore persists in many of the veins at very great depths.

In the vicinity of Idaho Springs the canyon, although wider than it is in the neighborhood of Forks Creek, is still narrow and the walls are studded with jagged or loose rock as they were left by the cutting of the stream and the action of the weather, but from a point a few miles above the town to the crest of the range the canyon bottoms are broad and the slopes are generally smooth and round, so that a cross section of the valley resembles in shape the letter U. This form of valley (shown in fig. 4, p. 11) is due to the scouring action of a glacier that originated near the summit of the range and flowed down the canyon to a point where the ice melted faster than it was supplied from above and where the forward movement of the glacier consequently stopped. Although all this happened ages and ages ago, the surface features above and below this point still present a striking contrast, for the work of the glacier has not yet been obliterated by weathering. The end of the glacier, which was only a few miles above Idaho Springs, is also marked by a moraine—a great accumulation of rounded and scratched boulders that were brought down by the ice and dumped at its lower end.

Both active and abandoned mines and many prospects may be seen on almost every slope of the canyon wall above Idaho Springs. In Gilpin and Clear Creek counties, as in most old mining regions, only a small proportion of the mines are in operation at any one time. Some of those that are not operated are "dead"—that is, their ore bodies have been entirely worked out—but many are idle only temporarily because of inefficient management or insufficient funds with

which to make further explorations for new ore bodies. Few veins are rich through their entire extent, and one company may exhaust its resources in exploring lean parts and its successor may continue the exploration for only a short distance and strike rich ore.

A number of the mines that are now idle, especially those near Lawson, Empire Station, Georgetown, and Silver Plume, were worked mainly for silver and have produced fabulously rich ore. Its unusual richness was caused by a process termed "downward enrichment," by which the silver in the upper parts of the veins was dissolved by surface waters and redeposited farther down in the earth. The ores so enriched do not persist to great depths, and on their exhaustion the mines working them are forced to shut down, for the unenriched ore below is too lean to be mined at a profit.

At Georgetown the train begins to climb the well-known "Loop" by which the railroad loops back over itself in ascending the steep mountain side. Above the Loop lies Silver Plume, shown in Plate VIII, which has been one of the most active mining camps in the State. It is reported that more than $29,000,000 in silver has been taken from the mountain north of the town.[6]

The traveler's interest in the things he sees above Silver Plume[6a] centers mainly in the engineering feat of scaling the steep mountain side and in the fine views he obtains during the ascent. After

[6] According to Bastin, the discovery of a gold-bearing vein near the present site of Central City by J. H. Gregory in 1859 stimulated prospecting throughout the drainage basin of Clear Creek, and many such veins were discovered. One of the most productive of these veins was discovered by George Griffith in the vicinity of Elizabethtown (now Georgetown) on August 1, 1859. In 1860 there was considerable excitement around Empire, but most of it was due to the discovery of rich placer gravel. The first valuable deposit of silver ore discovered (in September, 1864) was the Belmont lode, in Mount McClellan. Thus, as early as 1864 all the territory that the traveler will see on his trip to Mount McClellan was prospected in a crude way and to a certain extent developed. The development of mines, however, was greatly handicapped by the lack of means of transportation, both for bringing in supplies and for sending out the products of the mines. This lack was supplied to a great extent in 1870 by the building of what is known as the Georgetown branch of the Colorado & Southern Railway from Denver to Golden, but it was not until 1877 that this line reached Georgetown, and it was several years later before it reached Silver Plume.

Clear Creek County, of which Georgetown is the county seat, reached the peak of its metal production in 1894, since which time its output has been steadily declining until in 1914 it was worth only $884,615. In the next year the district began to feel the effect of the European war, and the value of its output of metals jumped to $1,124,225. In 1917 its metal output was valued at $1,631,219, in 1918 at $1,126,440, in 1919 at $644,332, and in 1920 at $526.369.

[6a] Since the description of the trip to Mount McClellan was written the line has been abandoned, and the traveler will have no opportunity to reach the summit of the mountain except by private conveyance.

zigzagging back and forth up the steep side of the valley the train passes around a point and runs up another valley to its head and then, after making several switchbacks, finds its way to the summit of Mount McClellan. The view from this point is shown in Plate IX. Mount McClellan is not on the Continental Divide but on a high spur that branches off from it toward the east. The water that falls on both sides of this peak finds its way into Clear Creek and eventually reaches the Gulf of Mexico, but that which falls on different sides of Grays and Torrys peaks,[7] which are on the Continental Divide, runs into streams that flow in diverse directions, part of it reaching the Gulf of Mexico and part of it the Pacific Ocean. These peaks are all more than 14,000 feet in altitude and are prominent features that may be seen toward the west, but they do not appear to stand so high above their surroundings as Pikes Peak and some other well-known mountain summits.

The slope on the east side of Mount McClellan is smooth and gentle, but that on the west side is precipitous, because the snow and ice that long ago lay on the west side, under the shadow of the towering summits of Grays and Torrys peaks, were more protected from the sun and wind than those on the east side, and consequently, during the great ice age, an enormous glacier lay in the angle between Mount McClellan and Grays Peak and cut out a great amphitheater in the rocks, which, because of its circular form, is called by geologists a cirque. If the traveler standing on the ragged crest of this old cirque and looking down 2,500 feet into it has a vivid imagination, he may still see the great glacier that once filled it and flowed down the valley nearly to Idaho Springs.

The route followed by the traveler throughout this trip is practically parallel with a high-tension electric transmission line of the Colorado Power Co. The power is developed at a large hydroelectric plant on Colorado River above Glenwood Springs and is carried to most of the mining camps in the mountains, crossing the Continental Divide three times and finally descending on the east to Georgetown, Idaho Springs, and Denver. The line may be distinguished by the high steel towers and the strip of cleared land along its right of way.

SOUTH PLATTE CANYON.

The canyon of South Platte River southwest of Denver offers many attractions to visitors from other parts of the world. There are no regular one-day excursions to this part of the mountains, but the train service on the narrow-gage Colorado & Southern Railway is so arranged that the traveler may easily visit such parts of the canyon as he deems most interesting and return to Denver the same day. If he is content with seeing the lower part of the canyon only

[7] The altitude of Grays Peak is 14,341 feet; Evans Peak, 14,260 feet; Torrys Peak, 14,336 feet; and Mount McClellan, 14,007 feet.

SILVER PLUME.

The once flourishing mining camp of Silver Plume lies in a deep canyon that heads in the Continental Divide. The mountain on the right is said to have yielded more than $29,000,000 in silver. The grade up the canyon is so steep that the narrow-gage road must loop back in places over itself to reach the camp. The railroad to Mount McClellan formerly zigzagged up the slope on the left. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.

MOUNT McCLELLAN.

Summit of Mount McClellan (on the right), 14,007 feet above sea level, and Grays and Torrys peaks on the Continental Divide (on the left). Note the great amphitheater or cirque about 2,500 feet deep in front of these peaks. This cirque was largely excavated by a glacier that flowed down to the north (right) by Silver Plume and Georgetown. Photograph furnished by the Argentine & Grays Peak Railroad.

he should go to the village of South Platte, 29 miles from Denver, but should he wish to see all its more rugged parts he should go as far as Estabrook, 52 miles distant. Many persons go to resorts farther up the canyon, even as far as Grant (66 miles), but this upper part of the canyon is not so rugged—it lacks the features that give to the lower part its peculiar charm. Those who go to the upper part do so on account of the fishing, which is reported to be unusually good.

On leaving the Union Station in Denver, the railway crosses South Platte River and runs up on the west side of the stream to the mountain front. At Sheridan Junction a branch line turns to the west (right) to Morrison, which is in the same valley as that in which Golden is situated. A mile up this line and on the main terrace that borders the river valley is Fort Logan, the largest military post in

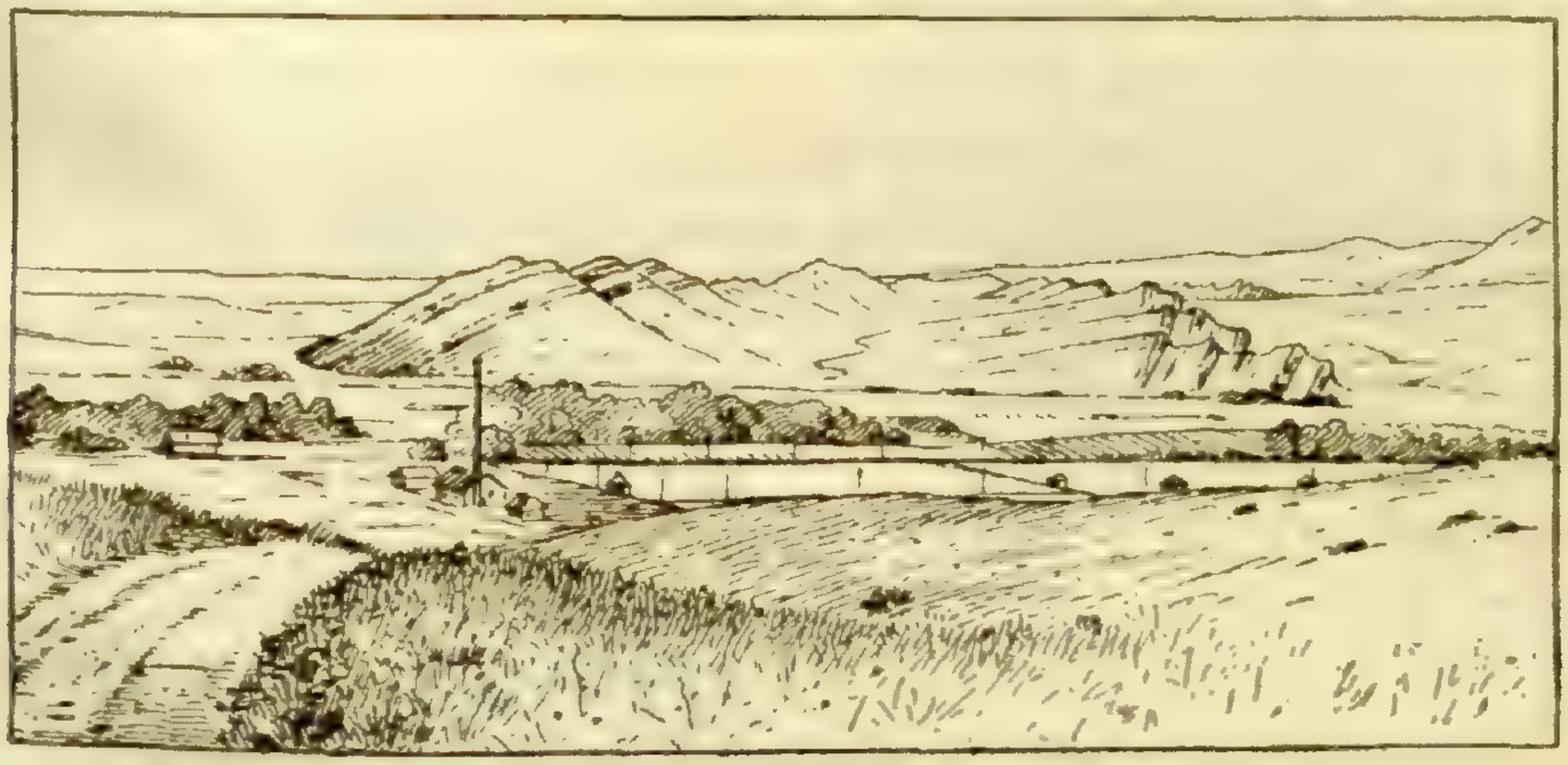


FIGURE 5.—Dakota hogback south of South Platte River, looking south. Note the eastward dip of the sandstone forming the hogback and also that of the red sandstone nearer the mountains. Settling reservoir of Denver waterworks in the middle distance.

Colorado. The train passes some fine country places and goes through large areas of irrigated lands in a high state of cultivation.

At a siding called Willard, 17 miles from Denver, the traveler may see on his right a sharp-crested ridge, which is formed by the upturned edge of the Dakota sandstone, the same rock that forms the sharp hogback at Plainview, on the "Moffat road." At first this ridge seems to stretch along the entire mountain front, and from the river bottom it appears almost as large as the mountains themselves, but on nearer approach it dwindles into comparative insignificance. The railway runs nearly parallel with this ridge for some distance, and then in following the river valley it turns more toward the west and cuts through it directly toward the mountains. The Dakota hogback on the south side of the river, as well as the outcrop of lower red sandstones, is shown in figure 5.

The reservoirs of the Denver waterworks, in which all sediment is allowed to settle before the water is turned into the city mains, are at Willard. The reservoirs are tastefully arranged and beautified with flowers, so that they make a very pleasing appearance. After passing the settling reservoirs beds of red sandstone similar to those which make so striking an appearance in the Garden of the Gods, near Manitou, may be seen across the river, dipping away from the mountains at an angle of about 70°. Most of the beds of rock on the mountain front have similar dips, showing that at the time the mountains were uplifted the beds of sedimentary rock were bent up in a great fold, the upper part of which has been worn away, leaving only the suggestion of the upfold in the steeply inclined beds. Before the train reaches the mountains the great steel pipe that carries the Denver city water may be seen at several places on the right, where it spans the ravines on steel bridges.

Just above Waterton the train enters the mountains by a canyon cut in the hard granite. Here the city water main passes over the railway and then plunges into a tunnel through a projecting spur. A large flume carrying water for irrigation may also be seen on the opposite side of the river, and it passes through the same spur that is pierced by the water main.

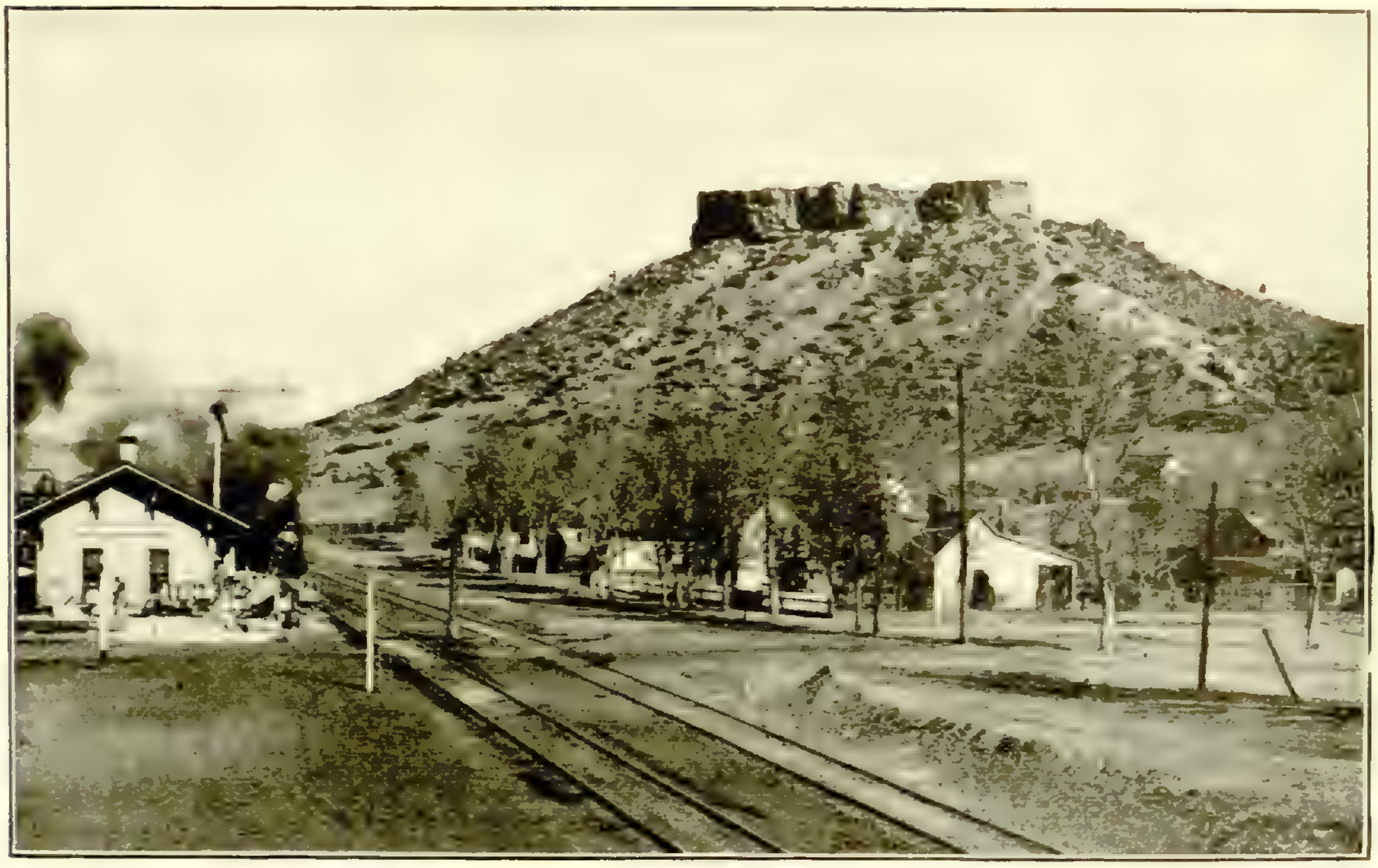
The canyon which the train is now following is narrow and tortuous, and its walls are generally rough and precipitous. It extends to the town of South Platte, at the junction of the two forks of the river. The course of the city water main on the opposite side of the stream may be followed by the white telephone poles up to the head gate. The canyon above this place differs in width in different localities. In some places it has a flood plain, but in others (as shown in Pl. X) it is so narrow that there is room only for the narrow-gage (3-foot) railroad beside the river, and this road has to curve as sharply as the stream.

The one feature that differentiates this canyon from others in the mountain region is the great number of trees that dot the rocky slopes on both its sides, but more particularly on the southern. The soft verdure of the evergreen trees relieves the ruggedness and the barrenness of the rocky walls, giving the canyon a picturesqueness seldom seen in other canyons of this region. Pine and spruce are the most common trees, but here and there stand groups of aspen, with their ever-moving leaves, which in summer give a softness to the slopes and in autumn add a blaze of glory to the somber canyon walls.

South Platte is at the junction of the South and North forks of the river. South Fork, which is much the larger stream, drains

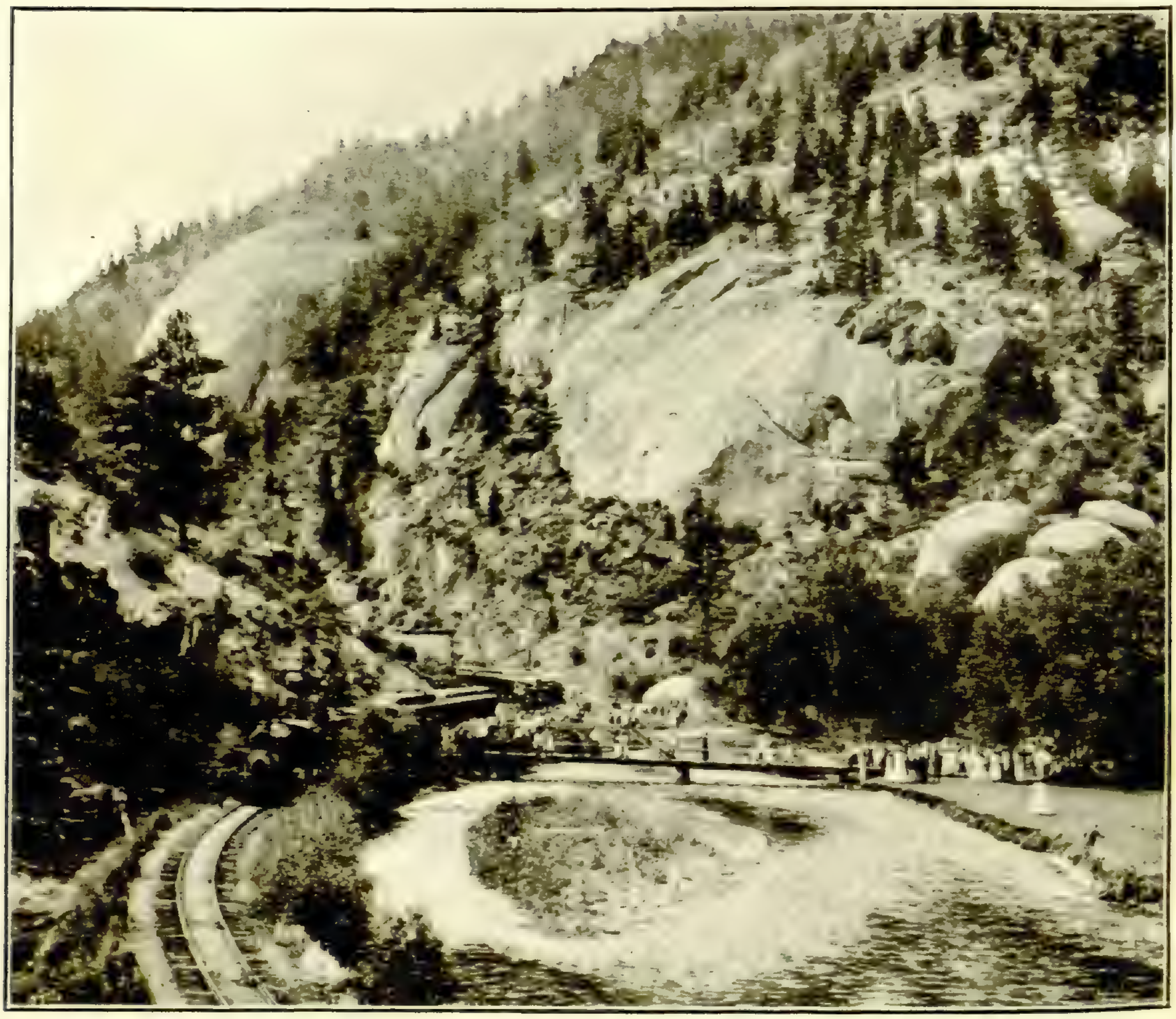
PLATTE CANYON.

Narrow part of Platte Canyon, where even a narrow-gage railroad can hardly find a foothold. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.



A. CASTLE ROCK.

A well-known landmark about 300 feet high, 33 miles south of Denver. It was first noted and named by the Long expedition in 1820. The cap rock, 60 or 70 feet thick, is made up of boulders of various sizes cemented together (conglomerate) and stands out prominently because it is harder than the underlying rock. Photograph by L. C. McClure, Denver.



B. DOME ROCK, PLATTE CANYON.

This picture illustrates the manner in which even the most massive granite may yield to the action of the weather. It peels off in successive curved layers much like the layers of an onion, leaving round or dome-shaped masses of rock which stand out in striking contrast to the towers and pinnacles that generally occur on the walls of the canyon. Photograph by L. C. McClure, Denver; furnished by the Colorado & Southern Railway.

nearly all of South Park and furnishes most of the water for the city's use. In the early autumn, when the snow has disappeared from the mountain tops, these streams are scarcely able to supply the city's needs. To remedy this deficiency a dam has been built some distance up South Fork valley to impound the water and hold it until needed. This dam has produced a fine body of water known as Cheesman Lake.

From South Platte the traveler may easily return to Denver, or if he chooses to go farther he can continue his journey up the canyon, which in some places takes on the aspect of a common mountain valley and in others is bounded by rocky walls several hundred feet high and so steep that they appear to be vertical. The massive granite, on weathering, tends to peel off like the layers of an onion, leaving a curved surface, in places like that of a great dome. (See Pl. XI, *B*.) Such a feature is well shown on a large scale at the station of Dome Rock. Where the granite is traversed by many fissures or joints it is so easily broken down that few ledges can be seen, and the surface is covered with a mantle of finely broken rock.

The roughest part of the canyon above South Platte lies between Cliff and Estabrook, where the gneiss is again exposed and makes a narrow, rugged defile. This canyon, like the one below it, has several aspects, which depend upon the character of the rock and upon the position of the joints.

OTHER TRIPS OF INTEREST.

The 70-mile circle trip through the Denver Mountain Park covers the most remarkable municipally owned park in the world. Within an hour's ride from Denver are the foothills of the park, backed by the towering peaks of the Continental Divide, with wild flowers, whispering pines, and singing torrents. The park includes a game sanctuary for buffalo, deer, and other Rocky Mountain animals, a free automobile camp, shelter houses, camping facilities, and hotels. The body of Col. W. F. Cody (Buffalo Bill), the noted scout and plainsman, rests on Lookout Mountain.

Many other beautiful and interesting drives may be made from Denver, and many railroad trips may be made that will well repay the traveler for the time spent, but some of these would consume more than one day and will therefore not be mentioned. One exception worth noting, however, is a trip to the Rocky Mountain National Park, which lies just back of Estes Park and includes Longs Peak. This park should be visited by all who delight in rugged mountain scenery.

MAIN LINE OF RAILROAD FROM DENVER TO COLORADO SPRINGS.

Denver.
Elevation 5,193 feet.
Population 256,491.[8]

Soon after leaving the Union Station at Denver, on the main line of the Denver & Rio Grande Western Railroad, the train crosses Cherry Creek near the place where Gen. Larimer built the first house, in 1858. As this creek heads out on the plains it is intermittent in its flow; in dry seasons little or no water runs in it at the surface, but when "cloudbursts" occur on its upper course a tremendous volume of water comes down, engulfing everything in its way. Such a catastrophe occurred in May, 1864, when great damage was done. Recently the channel of the creek, where it passes through the city, has been cemented, so as to prevent the loose sandy soil from washing away, and a boulevard bordered by trees has been constructed along it, giving its banks here the appearance of a park.

The Denver & Rio Grande Western Railroad traverses the manufacturing part of Denver, and at Burnham, 2 miles out from the city, it passes the shops of the railroad system. About half a mile beyond the shops is the interesting though unpretentious laboratory building erected by the National Radium Institute for experimental work in cooperation with the United States Bureau of Mines to devise a cheaper method of extracting radium salts from the ores found in Colorado. This work has been accomplished, and the plant has now passed into the hands of a private company to continue the work of extracting radium.[9]

A short distance farther along South Platte River may be seen on the west (right), and the railroad runs up its valley for a distance of about 15 miles. The valley is well irrigated and contains many fine farms and country places. Loretto Academy stands out clear and distinct as one of the landmarks of the upland on the farther side of the river. Fort Logan, just beyond, is a regimental Army post established about 25 years ago.

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[8] The figures given for population throughout this book are those of the United States census for 1920; for places that were not incorporated the figures given represent the population of the election precinct, township, or other similar unit; such figures are marked with an asterisk (*).

[9] The National Radium Institute was organized by Dr. Howard A. Kelly, of Baltimore, and Dr. James Douglas, of New York, not for private gain but for the purpose primarily of studying the curative properties of radium and secondarily to show that radium can be produced here at a much lower cost than abroad. When the institute was organized radium was selling for as much as $120,000 a gram. As Congress had failed to reserve for public use the land containing radium ores or to foster the development of the radium industry in this country, the National Radium Institute undertook to provide the ways and means for experimental work to determine whether or not the ores could be reduced at a smaller

Littleton is the county seat of Arapahoe (a-rap'a-hoe) County, so named from a tribe of Indians that formerly inhabited this part of the country. It stands in the midst of a rich agricultural district and has become popular as the suburban home of many of Denver's business men. Near Littleton are the W. F. Kendrick pheasantries, which are said to be the largest game preserve in the world. Here all kinds of wild fowl are raised, and golden pheasants may be seen wandering by the roadside like chickens on an ordinary farm.

Littleton.

Elevation 5,372 feet.
Population 1,636.
Denver 10 miles.

A short distance beyond Littleton the traveler may obtain a charming view on the right, across the broad, well-tilled valley of the South Platte, studded with clumps of cottonwood trees, to the Front Range, towering in the distance. Wolhurst, a fine country place built by the late United States Senator Edward Wolcott, is farther along on the right, just beyond milepost 13. After the death of Senator Wolcott the place was purchased by the noted mining man the late Thomas F. Walsh. It is now occupied as a country home by one of Denver's richest citizens.

At the small station of Acequia the railroad crosses the High Line Canal, one of those great irrigating ditches that are characteristic of the semiarid regions, which takes water from the South Platte and carries it far to the northeast, irrigating at least 100,000 acres of land that would otherwise be arid and unprofitable. The railroad follows the valley of South Platte River to a point a little beyond milepost 15, where it leaves the main valley and turns to the south (left) up Plum Creek. This creek also flows in a broad, flat valley, and the traveler, unless he observes closely, may not realize that the railroad has turned from the main valley into that of a tributary.

Near milepost 15 the entrance to South Platte Canyon may be seen in the mountain front, on the right. Here, in 1820, the exploring expedition of Maj. Long first came to the mountains, although it had traveled from the north for many miles in front of and nearly

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cost than abroad and thus to place radium within the reach of hospitals throughout the country.

The Bureau of Mines had already reached the conclusion that such a reduction in cost was possible, and an agreement was reached by which the bureau was to cooperate with the institute for the benefit of the people. The Institute leased claims in Paradox Valley, in southwestern Colorado, and the Bureau of Mines mined the ore and shipped it to Denver for treatment by the bureau. The work has been successful, and the bureau has patented a process by which radium was produced at a cost of about $40,000 per gram, or one-third its selling price. This patent may be used free of charge by anyone who cares to use it for the benefit of the American people.

All this valuable work has been done in the unpretentious plant at Denver. For further information the reader is referred to Bureau of Mines Bulletin 104.

parallel with them. The men were eager to climb the mountains, explore their wonderful peaks and valleys, and see the country that lay beyond, but a few days of hard climbing up the rocky slopes satisfied them that they could not reach the summit of the range in a short time and that mountain climbing was not so easy as it appeared from a distance; so they were content to proceed southward along nearly the route that is now followed by the Denver & Rio Grande Western Railroad. The entrance to the canyon may be seen from the train, but, owing to its many bends, the canyon does not appear to be an open cut through the mountain front.

In many places at the foot of the mountains the steeply dipping sandstone forms sharp hogbacks, which may be seen from the moving train, and, as the sandstone is mostly red, the traveler will soon learn to associate red sandstone and hogbacks with the foothills of the mountain front. These beds are very prominent near the mouth of Plum Creek and may be seen to good advantage from milepost 17, about 1½ miles up the creek.

The scenery of the lower part of the valley of Plum Creek is smooth and uninteresting. The surface is a rolling upland, which can not be irrigated from the South Platte because it lies too high above that river, and it consequently appears rather barren to those who are accustomed to a more humid climate. The only railroad station in this part of the valley is Louviers, which is merely a shipping point for the DuPont Powder Co., whose plant for the manufacture of high explosives is on the west (right) of the track.

Above Louviers Plum Creek swings eastward, and it is bordered on its east side by bluffs and mesas of white sandstone.[10] Although

[10] All the rock seen near the railroad track from Denver to a point beyond Palmer Lake is composed of fragments derived from the decomposition of the granite and gneiss of the mountains. This material, which consists mostly of quartz and feldspar, is known to geologists as arkose. The formation is called the Dawson arkose, and it is of the same geologic age as the formations about Denver that have been called the Denver and Arapahoe formations. Richardson, in the Castle Rock folio (No. 198) of the Geologic Atlas of the United States, describes the rock as follows:

"The Dawson arkose, derived from the Pikes Peak granite and associated rocks, was laid down under various continental conditions, chiefly as wash and fluviatile [stream] deposits accompanied by local ponding. During the accumulation of the arkose this region may be conceived of as a piedmont [foot of the mountain] area having a moist and temperate climate, an area in which the vegetation was characterized by the presence of many fig trees, palms, magnolias, poplars, willows, oaks, maples, etc., and which was occupied by *Triceratops* (huge three-horned dinosaurs), crocodiles, turtles, and other reptiles and by primitive mammals."

In other words, the material derived from the mountains was carried out on a nearly flat surface and deposited by the streams in much the same way as the streams of to-day are carrying the waste of the mountain rocks and spreading it over the low parts of the plains.

but a short distance from the upturned rocks along the mountain front, these sandstones lie practically horizontal, a fact which indicates that they are near the middle of the great downfold of the rocks east of the Front Range. Figure 6 represents the edges of the upturned rock beds as they would appear if they had been cut by a giant knife at right angles to the trend of the mountain range.

Louviers.

Elevation 5,675 feet.
Denver 21 miles.

The Atchison, Topeka & Santa Fe Railway, which has been on the east (left) side of the train since it left Denver, passes over the Denver & Rio Grande Western Railroad at the town of Sedalia. The upland on the east is here nearer the track than it is farther north, and it stands out as a plateau with a steep or even vertical front. Some of these steep slopes are merely projecting points of the highland, but others are parts of hills that have been isolated from

Sedalia.

Elevation 5,835 feet.
Population 365.*
Denver 25 miles.

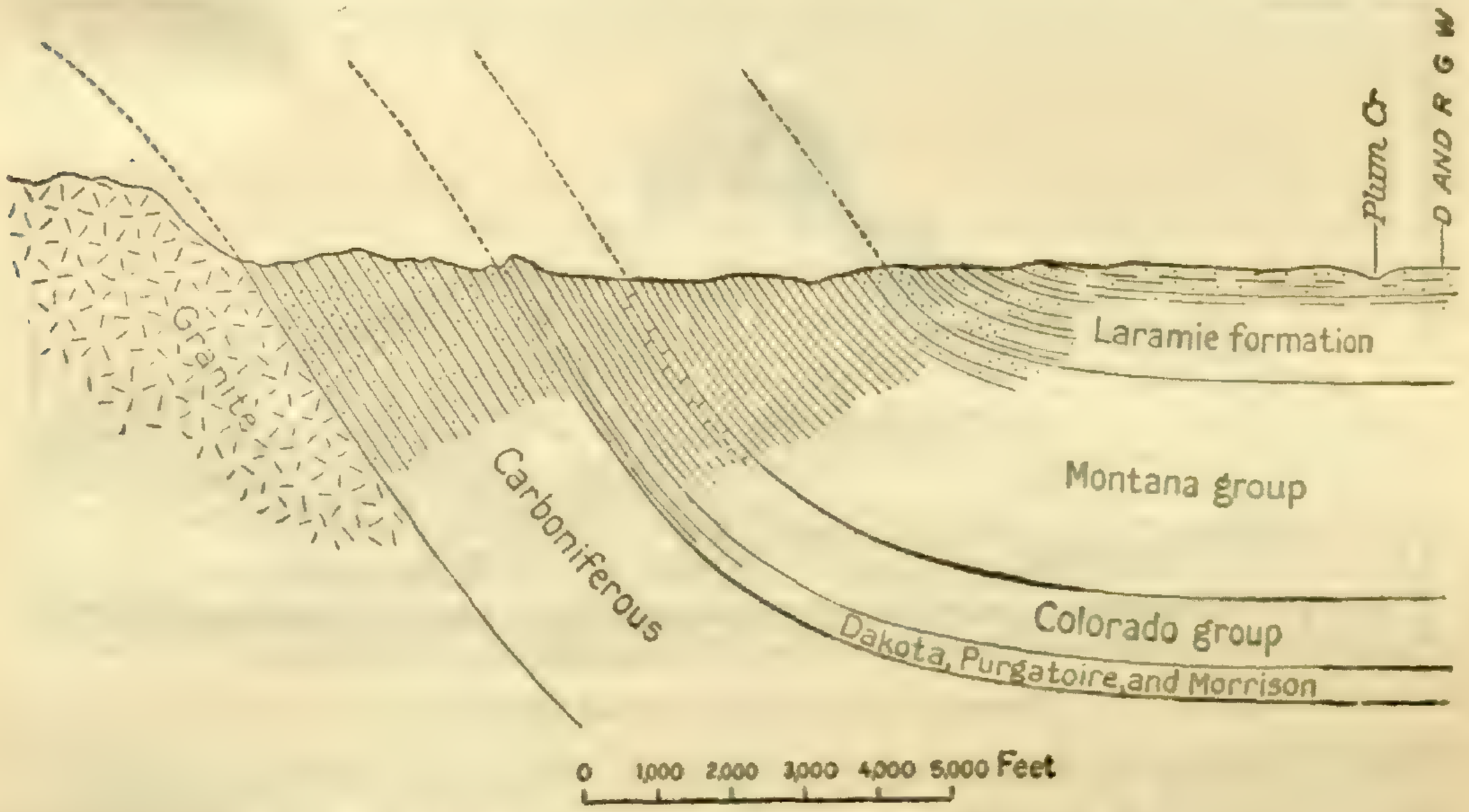

FIGURE 6.—Section at mouth of Platte Canyon.

it by the cutting of the streams. Such isolated remnants of a once extensive plateau are very conspicuous on the west (right) of the road. A hill of this kind in the East would not be called by any special name, but in the West, and especially in the Southwest, a flat-topped hill is almost universally called by the Spanish name mesa, meaning table. Near Sedalia are the forks of Plum Creek, one of which comes from the south and the other from the east. The one that comes from the south offers the more direct course for the railroad, but the one that comes from the east is the longer and has the better grade, so it was selected, even though its course is more roundabout.

The most prominent of the mesas is Castle Rock, which may be seen far ahead on the right soon after the train passes Sedalia. When first seen it is so far away that it seems to be only a small hill, but as the train proceeds it becomes more conspicuous, until at a siding called Plateau it appears on the right as a very prominent conical

hill surmounted by a thick, square block of rock. This mesa was first mentioned in the report of the exploration of Maj. Long, in 1820, and on account of its resemblance to an old ruin was called Castle Rock.

As the train approaches milepost 32 the traveler may see that the railroad is built around the foot of Castle Rock mesa, which is about 300 feet high and has a cap rock 60 or 70 feet thick. This mesa is shown in Plate XI, *A*, and in figure 7.

Castle Rock.

Elevation 6,218 feet.
Population 461.
Denver 33 miles.

The lower part of the mesa is composed of soft, friable beds of the Dawson arkose, but the cap rock is a coarse conglomerate of pebbles and boulders of crystalline rocks of all sorts that have been washed out from the mountains and of a volcanic rock (rhyolite) which caps also some of the adjacent mesas. These materials were washed out of the mountains by streams of water and dropped as sheets of gravel and boulders upon the surface of the land. The county seat of Douglas

FIGURE 7.—Castle Rock from the north.

County, named in honor of Stephen A. Douglas, stands at the base of the mesa and bears the name Castle Rock. It was formerly noted for its stone quarries, the remains of which still disfigure the mesas, but the increasing use of cement in construction work has so depressed the market for ordinary building stone that the quarrying industry has nearly disappeared. Samples of the stone may be seen in the Douglas County High School building, on the right as the train enters the town, and in the station building of the Denver & Rio Grande Western Railroad.[11] This stone was once molten lava

[11] According to Richardson the rhyolite is said to have been first quarried about 1876, and it is reported that up to 1914 about 30,000 carloads had been marketed. The stone has been extensively used for building in Denver, Colorado Springs, and Pueblo, where it has given general satisfaction. The quarries, to which railroad spurs have been constructed, are near the town of Castle Rock. The stone is readily accessible, is easily worked, is of pleasing gray to pinkish color, stands the weather well, and is sufficiently strong for ordinary purposes, although the more porous varieties are not adapted for use where great strength is desired. In recent years the production of this stone has fallen off because of the competition of other building materials.

that was poured out as a thin sheet over the surface of the country, after the Dawson arkose was deposited but before the coarse materials of the Castle Rock conglomerate were spread over the plain.

In following the valley of Plum Creek from Sedalia to Castle Rock the railroad swings far to the east of a direct line from Denver to Colorado Springs. After passing Castle Rock it turns back toward the mountains, its course being nearly due south to Palmer Lake, and the prolongation of this course would lead almost directly to Pikes Peak. This majestic mountain is too nearly straight ahead to be visible at many points, but here and there as the train swings around some of the numerous curves it may be seen in the distance towering far above the surrounding summits.

To those accustomed to the more humid regions of the East, with their dense cover of vegetation, the open spaces of the West, the red rocks, and the strong yellow light of the plains are here the most striking features. The wonderful color effects of this region are beautifully expressed by Helen Hunt Jackson, Colorado's most gifted author:

> Colorado is a symphony in yellow and red. And as soon as I had said the words, the colors and shapes in which I knew them seemed instantly to be arranged in my thoughts; places miles apart began to knit themselves together into a concerted and related succession; spots and tints I had only vaguely recognized became distinct and significant, each in its order and force; and more and more as I looked from the plains to the mountains and from the mountains to the plains, and stood in the great places crowded with gay and fantastic rocks, all the time bearing in mind this phrase, it grew to seem true and complete and inevitable.

Mesas composed of white arkosic sandstone are seen on both sides of the railroad, but one on the right, 2 or 3 miles beyond Castle Rock, is the most prominent. This mesa, which is known as Dawson Butte, furnished the geologic name of the formation—the Dawson arkose. Just beyond milepost 37 there appears, seemingly from behind this mesa but in reality far beyond it, a jagged mass of red granite, which towers 1,000 feet above the general level of the Front Range plateau. This rugged mountain, known as Devils Head, is utilized by the Forest Service as a lookout station for the detection of forest fires. (See Pl. XV, *B*, p. 31.) On its lonely summit is stationed, throughout the summer, an observer whose duty it is to scan continually the surrounding mountain region for forest fires, and if he discovers one to notify at once, by telephone, the superintendent of the Pike National Forest, so that all the rangers can be called together to fight the fire. A more extended description of what the Government is attempting to do for the conservation of the forests is given below by Smith Riley, former district forester.[12]

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[12] Colorado lies in the zone of slight precipitation and hence of irrigation, and the supply of water for this purpose comes from the mountains, where

Above Dawson Butte the railroad continues up the valley of East Plum Creek, winding around a projecting spur of the plateau on the east to the village of Larkspur, from which a stage line runs to the resorts in Perry Park, 4 miles to the west. This is a natural parklike area at the foot of the mountains, made picturesque by natural monu-

Larkspur.

Elevation 6,668 feet.
Denver 43 miles.

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the moisture falls as snow during the winter. The presence of trees controls and prolongs this stream flow by preventing erosion and retarding the melting of snow in the spring and early summer.

The forest on the mountains is composed of many different species of trees, and the range in elevation of these species is controlled largely by moisture and temperature. The piñon or nut pine and cedar trees are found near the plains or in the zone of smallest precipitation. Above this zone, as the precipitation increases, is that of the western yellow pine (Pl. XIV, *C*) and Douglas fir, with blue spruce on small tracts. Above the zone of yellow pine is the zone of lodgepole pine (Pl. XXXVI, *B*, p. 76) and above this, extending to timber line, is the zone in which Engelmann spruce (Pl. XIII, *B*) and alpine fir are intermixed. Throughout the zones of yellow and lodgepole pine and even in that of Engelmann spruce quaking aspen occurs in abundance. This tree, which presents a wonderful richness of autumnal coloring, has a marked tendency to seed quickly areas that have been severely burned. As it grows rapidly it soon forms a cover and acts as a "nurse tree," under which conifers that require more moisture start to grow and ultimately take possession of the area and kill out the aspen. Several varieties of cottonwood are found in the moist stream bottoms, in the zones of the yellow pine and piñon, and out on the plains.

One of the white or five-needle pines grows on exposed slopes high in the zone of the yellow pine. This tree, which is called limber pine, has little commercial value but is very picturesque because of its gray-green foliage and whitish bark. Its pale-yellow cones are larger than those of any of the other pines in this region, and many of the trees are distorted into curious and picturesque shapes by the severe climatic conditions under which they grow.

In the zone of the lodgepole pine and on the more exposed ridges there is another five-needle pine called bristlecone or sugar pine. This tree derives its names from the recurved prickles or thorns at the extremity of the cone scales, and from the exudations of resin on the surface of the needles or leaves, which when dry look very much like particles of sugar.

To maintain a cover for an even stream flow and protect the supply of timber all the more extensive drainage basins of the United States have been included in national forests. There are seventeen such forests in Colorado, comprising over 13,000,000 acres of mountainous country.

A forest, which is based upon natural subdivisions and administrative lines, contains from 400,000 to 1,600,000 acres and is in charge of a forest supervisor and a corps of assistants. Every forest is further divided into ranger districts, each containing from 50,000 to 200,000 acres. Such districts are in charge of rangers, who police them and look after all business pertaining to the national forest.

The Pike National Forest includes the mountains west of Denver and Colorado Springs. It includes most of the drainage basins from which Denver, Colorado Springs, and many smaller towns, having altogether a population of about 350,000, derive their domestic water supply. In addi-

A. RESULT OF A RECENT FOREST FIRE.

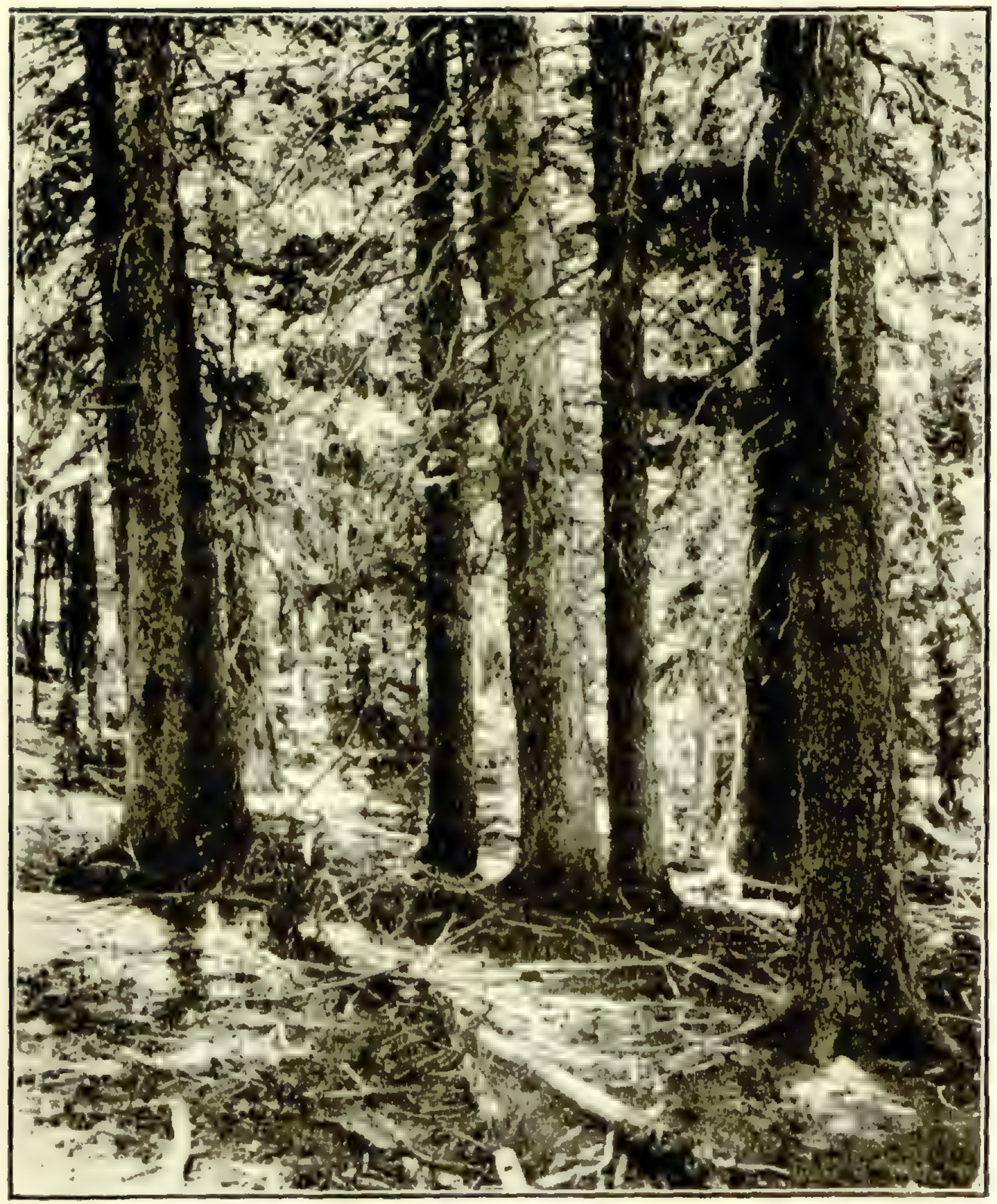
Scarred and blackened tree trunks and half-burned logs mark the path of a recent fire through the national forest. Photograph by the U. S. Forest Service.

B. RESULT OF AN OLD FOREST FIRE.

An old "burn" in a national forest. Its pathway is marked by the white skeletons of the dead trees, which are ready to fall in a hopeless tangle when struck by a hard wind. Photograph by the U. S. Forest Service.

A. MARKING MERCHANTABLE TIMBER.

Marking trees in midwinter for a national-forest timber sale. Photograph by the U. S. Forest Service.



B. ENGELMANN SPRUCE.

A typical stand of Engelmann spruce, which grows only at high altitudes. Photograph by the U. S. Forest Service.

ments of tilted and highly colored sandstone. Although less known than the Garden of the Gods, near Manitou, it is similar in general appearance and by many is regarded as fully equal to it in natural beauty. In these castellated rocks those who have a vivid imagination can see mystic monuments and towers, battlemented walls, minarets and steeples, and the remains of vast cities that still reflect

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tion to this supply its streams furnish water for irrigating 400,000 acres of rich agricultural land at the foot of the mountains.

The region now included in this forest furnished an immense amount of timber during the early development of local industries, about 500,000,000 feet b. m. having been cut prior to its establishment as a national forest. In the mountains farther west, particularly at Howard, travelers may notice rows of domelike structures looking like large beehives of the old-fashioned wicker type. (See Pl. XIV, *B*.) These are charcoal kilns. They represent all that is left of the charcoal industry, which, before coke was available, furnished fuel for smelters, greatly to the detriment of the timber stands of the regions.

In Gilpin County considerable areas of forest land were practically denuded, for trees of all sizes and even stumps were removed and utilized. This cutting was followed, from time to time, by fires which fed upon the "slash" left on the cut-over areas and killed the remaining trees. The bare hills then permitted a rapid run-off of water after heavy rains, which caused considerable destructive erosion. Similar conditions mark other parts of the Pike National Forest, but erosion has not cut so deeply into the slopes, and owing to generally favorable conditions, many areas have naturally become reforested.

In the early days all ranch buildings were constructed of logs, and even furniture was made by the settlers. The trees also furnished the entire supply of fuel. In many localities they serve the same purposes today—the ranchers and new settlers put up their own buildings of logs obtained from the national forest under free-use permits, or established ranchers can purchase at a low price, equal to the cost of administering the sale.

From 1875 to 1895 most of the railroads of the mountain region were built, and practically all construction was done with local timber. Most of the cutting was done by small operators, with sawmills of 6,000 to 10,000 feet b. m. daily capacity, who would locate or purchase a small tract of timber land and then cut not only that but the timber on adjoining Government land. The operators of that day paid little or no stumpage for their timber and cut only that which was the most easily obtained or which was best suited to their purpose.

Since 1905, when the forests came under the jurisdiction of the Forest Service, the Government's timber has been sold to private purchasers at fair rates of stumpage, and cutting has been restricted to trees whose removal would benefit the remaining stand. The stumpage price charged in each sale is the difference between the market price of the product and the estimated cost of production plus a liberal allowance for profit to the operator.

The amount of timber cut in the Pike National Forest for the year ending June 30, 1921, was 3,420,000 feet b. m., for which $4,960 was paid the Government for stumpage. In addition, about 1,000,000 feet b. m., mainly of dead material, was granted free to settlers and miners for their own use.

The area of the Pike National Forest is 1,256,112 acres, of which 162,956 acres is patented or privately owned, and 108,000 acres is above timber line.

in the massiveness of their ruins some of their former grandeur. To the geologist these buttes and plateaus are also the ruins of a former age, but instead of being carved by man and representing cities that have passed away they were carved by water and wind from an older and higher land surface that carried its own particular types of plants and animals and that had a climate which may have been very different from the climate of to-day. Compared with these remnants of this old land surface the most ancient ruined cities are as the works of yesterday.

Larkspur Butte on the east and Raspberry Butte on the west are small remnants of this old surface. Beyond them the upland has been cut away, leaving a rather broad valley in which stands the

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The present stand of timber in the forest is estimated to be 1,100,000,000 feet b. m., of which 620,000,000 feet b. m. is considered to be in commercial stands and 480,000,000 feet b. m. in protection stands.

The following list gives the species in the order of their abundance in the present merchantable stands, the names in parentheses being those often used by local timbermen: Engelmann spruce (white spruce), yellow pine (immature timber is called blackjack), Douglas fir (red spruce), lodgepole pine, white pine, limber pine (white pine or piñon), bristlecone pine (sugar pine or piñon), alpine fir (white fir), white fir (balsam or black balsam), Colorado blue spruce (water spruce), and aspen (quaking asp). Of these, Douglas fir is the most valuable for railroad ties and lumber for other purposes, and yellow pine second.

When an application for a timber sale is received by the Forest Service it is first necessary to determine whether the timber applied for should be sold. Where dead timber is available and will answer the purpose its use is encouraged. The object of cutting green timber is to improve the stand by the removal of the mature and defective trees, which are growing very slowly, and to thin crowded groups of trees, leaving a stand of younger thrifty saplings and poles with plenty of growing space and permitting young trees to come in wherever there is not already a sufficient stand. In order to improve the stand and keep it in the best of condition for future growth it is necessary to base the time and method of cutting on the needs of the forest rather than on the desire of the operators. In the slow-growing stands of this forest it will generally be from 30 to 50 years or more after the first cutting before the area should be cut over again.

In a Forest Service timber sale each green tree to be cut is designated by blazing and stamping it with a "U. S." stamp. This marking is necessary in order that the trees which are to form the basis of the future stand will not be destroyed. (See Pl. XIII, *A*.) After the marked trees are cut and skidded or hauled to a central point, the material is scaled or measured by a forest ranger and there sawed into lumber by a small mill. Contracts for the sale of green timber provide for the disposal of the brush and débris resulting from the cutting. Where there is a serious menace of fire the purchaser is required to pile the brush and burn it when there is no danger of the fire spreading. Where the danger from fire is not so great, or where some protection of the soil is needed to induce reproduction, the purchaser is required to trim the tops and scatter the brush so that it will lie close to the ground, where it will absorb moisture and decay rapidly. The proper

A. A FOREST NURSERY.

The Monument nursery of the U. S. Forest Service, in which young trees are grown from the seed. This nursery contains 1,729,000 seedlings and 810,000 transplants, which later will be used for reforesting some of the burned-over areas. Photograph by the U. S. Forest Service.

B. OLD CHARCOAL KILNS.

Into such kilns as these much of the forest of the Rocky Mountains has disappeared. The charcoal which it made was used before coke became available for smelting ores. Photograph by the U. S. Forest Service.

C. YELLOW PINE.

Typical stand of yellow pine in the Pike National Forest. Photograph by the U. S. Forest Service.

A. A PLACE FOR ARTIFICIAL REFORESTATION.

A tract on the mountain back of Palmer Lake burned so severely that artificial reforestation is necessary. The mountain top here is almost a perfect plain (a peneplain). Pikes Peak, in the distance, rises nearly a mile above its surface. Photograph by the U. S. Forest Service.

B. FIRE-LOOKOUT STATION.

On Devils Head Mountain, in the Pike National Forest. The observer stationed here is on the lookout for all forest fires occurring in an area of 600,000 acres. In case of fire he notifies by telephone the superintendent at Denver and the local forest rangers, who at once endeavor to put out the fire before it spreads and destroys valuable timber. Photograph by the U. S. Forest Service.

hamlet of Greenland. After passing this village the train turns more toward the southwest and pursues a direct course toward the low gap which separates the headwaters of East Plum Creek on the north from those of Monument Creek on the south. This gap is at the foot of the mountains and is marked by Palmer Lake, the highest point on the line between Denver and Pueblo. This lake and its relation to the mountain front are well shown in Plate XVI, *B*. The lake and town were named for Gen. Palmer, the organizer, first president, and inspiring genius of the Denver & Rio Grande Railroad. A more extended account of Gen. Palmer and his

Greenland.

Elevation 6,919 feet.
Denver 47 miles.

Palmer Lake.

Elevation 7,237 feet.
Population 160.
Denver 52 miles.

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disposal of brush is the most necessary measure for the protection of a cut-over forest from fire.

In the early days of settlement in this country the forest suffered considerably from fires. (See Pl. XII, *A* and *B*.) The present fire-fighting methods and organization were unheard of. In 1869 a fire started by hunters on Pikes Peak is said to have burned intermittently for eight months and to have covered many thousands of acres, though there were several times during this period when a small crew of men could have extinguished it. Similar fires covered about 250,000 acres in the Pike National Forest, and of this area 60,000 acres is not restocking but must be reforested.

While visiting Colorado Springs the traveler will notice burned-over areas on the slopes of Pikes Peak. Several cities and towns procure their water supply from the slopes of this mountain, so it is of great importance that the forest growth be extended and maintained. An agreement has been entered into between the Forest Service and the cities of Colorado Springs, Manitou, and Cascade that the service shall reforest these slopes as rapidly as the funds available will permit. Already about $100,000 has been expended in this work, and complete plans have been formulated for its continuation until tree growth has been established upon the entire area suited to the purpose. In making the trip to Pikes Peak over the automobile highway the traveler passes through several of these plantations.

In order to accomplish this planting a nursery has been established just west of the town of Monument (Pl. XIV, *A*). At the present time over 1,500,000 tree seedlings and 600,000 transplanted trees are growing in this nursery. These trees will be planted in the mountains when they are two to three years old at a distance of 6 to 8 feet apart. During 1920 the area thus reforested comprised 738 acres and the planting required 570,000 trees.

Forest fires still cause great destruction in the national forest. (See Pls. XII, *A*, *B*, and XV, *A*.) The possibility of fires in the Pike National Forest is great, because eight railroads traverse it, 5,000 people live in it, and 250,000 tourists seek recreation within its borders. On the summit of Devils Head Mountain the Forest Service has established a fire-lookout station (Pl. XV, *B*), at which an officer is detailed to watch for fires during spring, summer, and autumn. This officer is in direct communication by telephone with the supervisor's office in Denver and with the rangers whose districts he overlooks. As soon as a fire is discovered he gives its location promptly and accurately so that the rangers can start with men, tools, and supplies to fight it.

work will be found on pages 54–60. The town of Palmer Lake is composed largely of cottages for summer guests who come here for health and recreation. The railroad station is 1,957 feet higher than Denver and 1,248 feet higher than Colorado Springs. Glen Park, an assembly ground modeled after the famous Chautauqua of New York, is about a mile from the station. The mountain front west of the lake rises abruptly, as shown in Plate XVI, *B*, to a height of 1,800 feet above the level of the lake. The summer cottages nestle in the ravines at the base of the mountain and afford the inhabitants the advantages and attractions of both the plains and the mountains.

The mountain front rises abruptly from the plain without foothills of any kind. The reason for the absence of foothills is that the rocks of the plains, when they were bent by the upthrust of the mountains, could not stand the strain to which they were subjected, and in many places they broke and the lower crystalline rocks of the

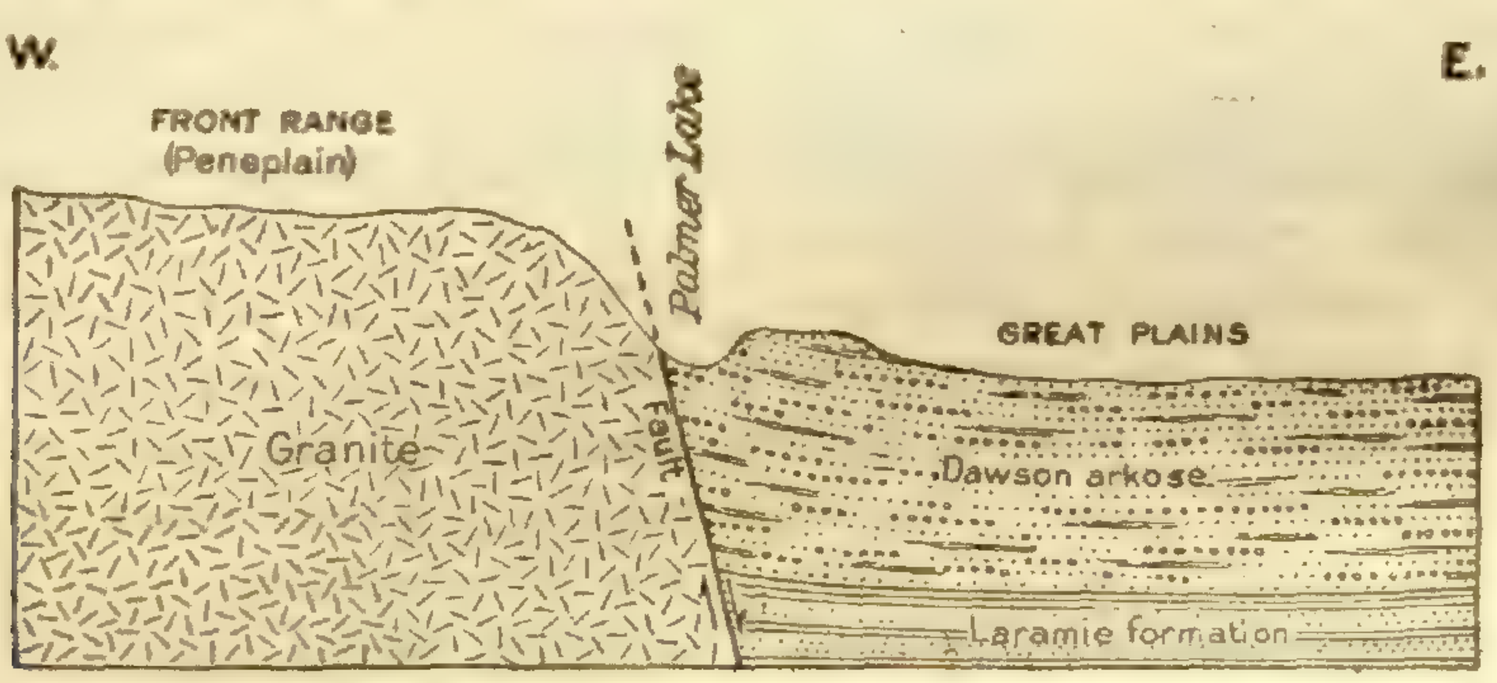

FIGURE 8.—Sketch section through Palmer Lake, showing fault. The granite on the west has moved up (see Pl. LXXXVII, p. 216) with reference to the rocks of the plains.

mountains were forced up into direct contact with the broken edges of the soft, flat-lying rocks of the plains, forming what is called a fault. The positions of the rocks and their relations are shown in figure 8. The effect of this fault has been much the same as that of the small faults shown in Plate LXXXVII, *A* and *B* (p. 216).

From Palmer Lake to Colorado Springs the railroad extends down the valley of Monument Creek, so named from the pinnacles and columns of white sandstone (Dawson arkose) that are left by the irregular weathering of prominent outcrops. The first conspicuous example is on the east (left) of the road, where a mass of the sandstone has weathered into a form resembling an elephant. (See Pl. XVI, *A*.) On account of this resemblance it is generally known as "The Elephant." The valley immediately south of Palmer Lake is narrow, but in a short distance it swings to the east and at the village of Monument is broad, irrigated, and well farmed.

Monument.
Elevation 6,972 feet.
Population 192.
Denver 56 miles.

The next station on the railroad is Edgerton (see sheet 2, p. 84), which is the point of departure for those who wish to visit Monument

GEOLOGIC AND TOPOGRAPHIC MAP

OF THE

RIO GRANDE ROUTE

From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
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1922

EXPLANATION

			Age	Thickness in feet
B	Gravel on mesas and terraces		Pleistocene	
C	Conglomerate deposited by streams (Castle Rock conglomerate)		Tertiary (*Oligocene*)	300
D	Arkosic (fragments of granite) conglomerate (Dawson arkose) Near Denver the beds equivalent to the Dawson arkose are divided into two formations:		Tertiary (*Eocene*)	2,000
D_2	Shale and sand (andesitic) (Denver formation)			800±
D_1	Conglomerate, sandstone, and shale (Arapahoe formation)			700
G	Sandstone and shale with coal beds (Laramie formation)		Upper Cretaceous	1,200
I	Dark marine shale with sandstone at top (Montana group)	Fox Hills sandstone / Pierre shale		8,000
J_1	Dark marine shale and limestone (Colorado group)			1,000
M	Two beds of sandstone separated by shale	Dakota sandstone / Purgatoire formation	Lower Cretaceous	300
N	Red and green shale and sandstone (Morrison formation)		Cretaceous?	200
T	White and red sandstone, red shale and gypsum at top	Lykins formation / Lyons sandstone	Carboniferous (*Permian (?) and Pennsylvanian*)	2,825
	Mainly white arkosic sandstone (Fountain formation)			
U	Limestone and quartzite	Millsap limestone	Carboniferous (*Mississippian*)	250
		Manitou limestone	Ordovician	
		Sawatch sandstone	Cambrian	
X	Granite		Pre-Cambrian	
Y	Lava flows (basalt and rhyolite)		Tertiary	

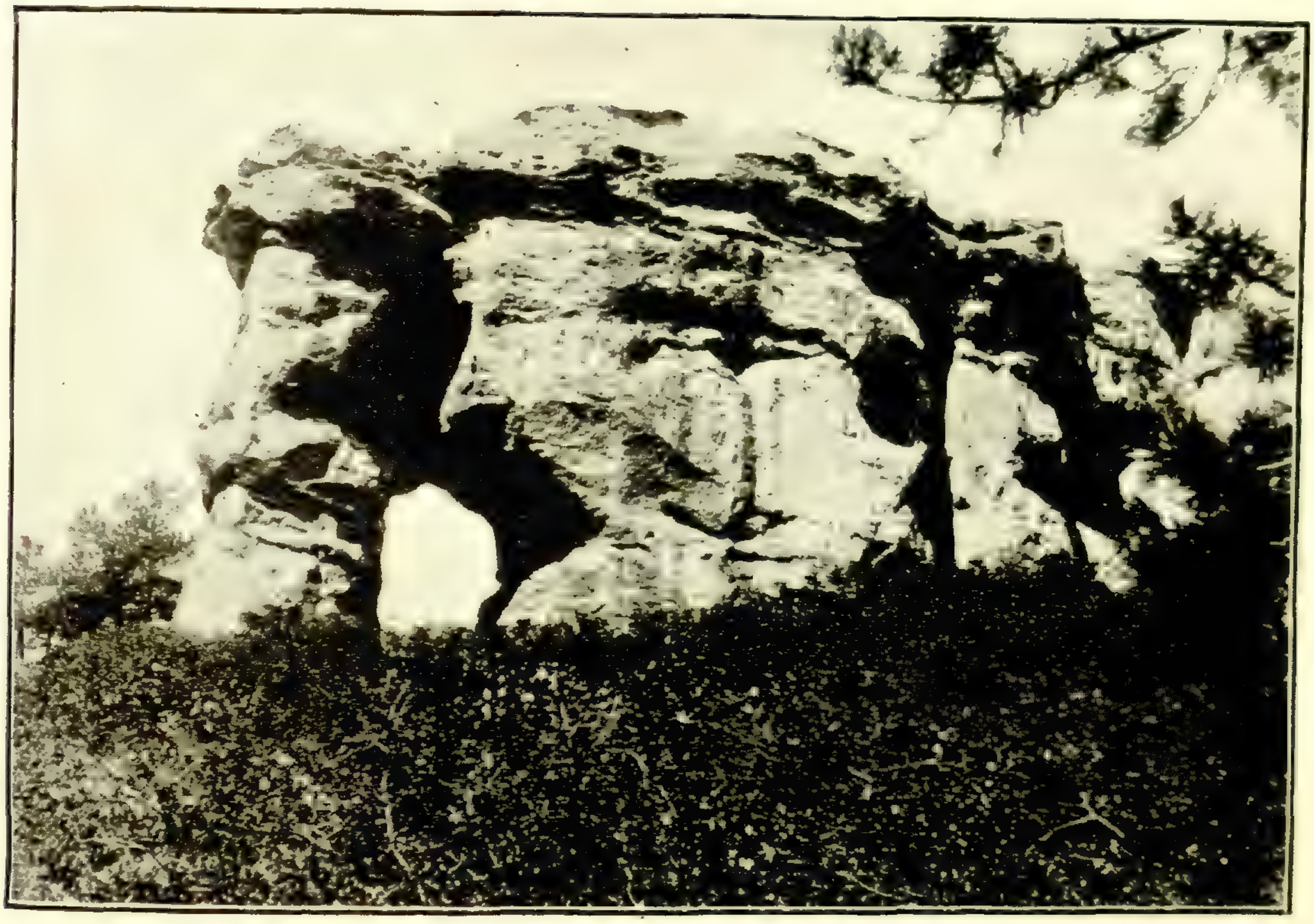
Fault

Scale 1/500,000
Approximately 8 miles to 1 inch
0 5 10 Miles
0 5 10 15 Kilometers

Elevations in feet above mean sea level

The distances from Denver, Colorado, are shown every 10 miles. The crossties on the railroads are spaced 1 mile apart.

Relief shading by R. W. Berry



A. "ELEPHANT ROCK."

Just after passing Palmer Lake the guide on the train will call attention to the "Elephant," one of the grotesque remnants of the Dawson arkose which has weathered into a form resembling an elephant. Photograph by G. B. Richardson.

B. PALMER LAKE.

On a hot day in summer one of the most refreshing sights between Denver and Colorado Springs is the little sheet of water known as Palmer Lake. It lies on the divide between the Arkansas and the Platte and also at the foot of the Front Range, which shows on the right. Photograph furnished by the Denver & Rio Grande Western Railroad.

A.

B.

CAPPED PINNACLES IN MONUMENT PARK.

On some of the sandstone pinnacles weathering has gone so far that the columns are nearly cut through; in time this will be accomplished, but others will be developed as the cliff is slowly worn back. Photographs by W. H. Jackson.

C. THE "MAJOR DOMO," GLEN EYRIE.

The spires and monuments of Glen Eyrie are as picturesque and fantastic as those of the Garden of the Gods; in fact, they are the northward continuation of the same group of rocks. Photograph by W. H. Jackson.

Park, 2 miles to the west, near the foot of the mountains. This park is also noted for the fantastic forms assumed by the rocks as they are cut away by the elements. A few of the columns in which iron oxide has cemented certain layers, forming a cap that protects the layers below from rapid decay, are shown in Plate XVII, *A* and *B*.

Edgerton.

Elevation 6,417 feet.
Denver 66 miles.

In its course down Monument Valley the railroad is built on the Dawson arkose, but the lower part of that formation is composed of sandstone that decays easily, and the rocks do not form buttes or mesas. Near Pikeview the arkose is cut through, and the Laramie, or underlying formation, is exposed. Its outcrop is not conspicuous in the valley, but it forms a line of white sandstone cliffs that may be seen for a long distance to the east (left). This formation is the same as that which carries coal northwest of Denver, and were overlying formations removed it would be possible to walk on this sandstone continuously from Pikeview to Denver. It also carries coal beds in the Monument Creek valley, and the principal business at Pikeview is mining coal. The coal is mined by a shaft about 250 feet deep, but a short distance to the south it comes to the surface. It is of low rank and slacks or falls to pieces quickly when exposed to the atmosphere. As it comes from the mine it carries a large percentage of water, which makes its heating power low, but despite its inferior rank it competes as a domestic fuel with coals which are of a higher rank but which have to be shipped a much greater distance. Pikeview was so named on account of the magnificent view that may be had here of Pikes Peak, about 10 miles distant (Pl. XVIII). On a clear day the smoke of ascending trains can be clearly distinguished, and even part of the "Cogwheel Road" to the summit can be seen.

Pikeview.

Elevation 6,199 feet.
Denver 70 miles.

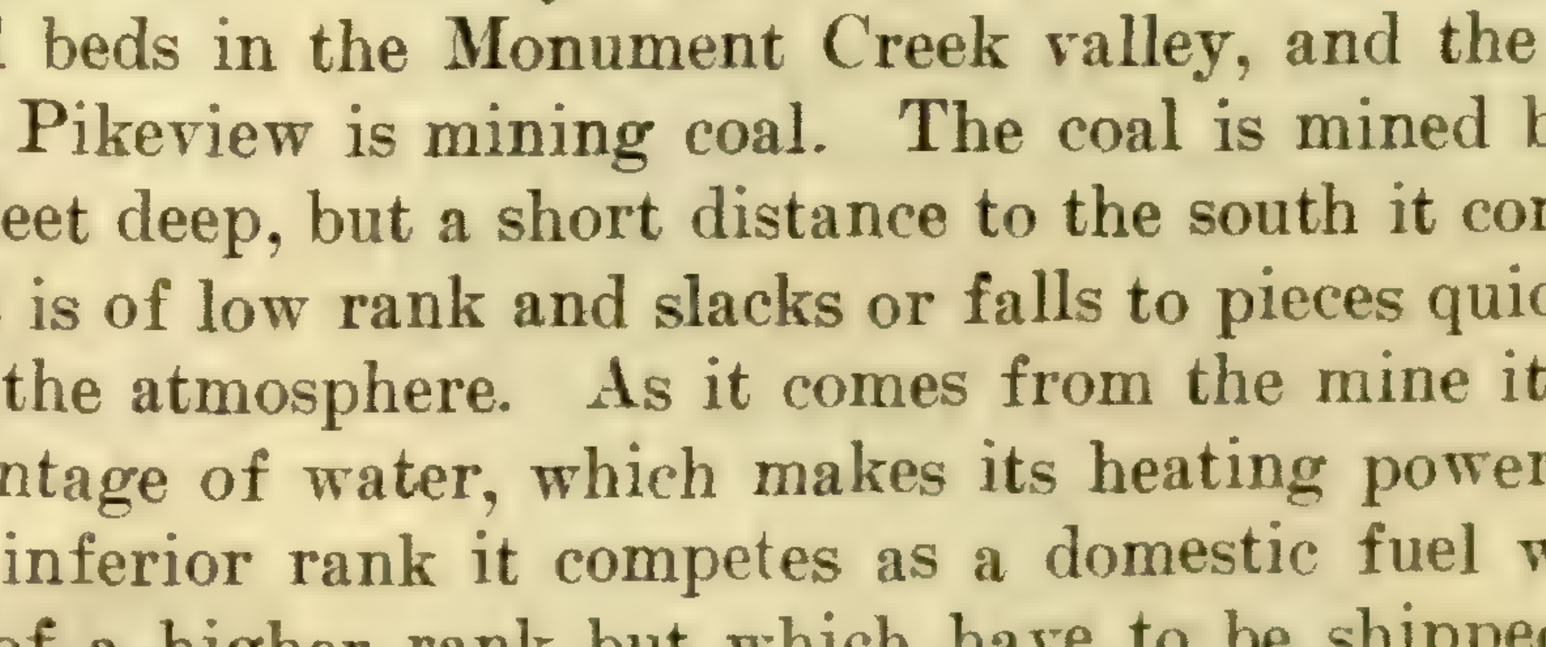


FIGURE 9.—Section at Pikeview, showing the fault that separates the rocks of the plains from those of the mountains.

The position of the coal-bearing rocks beneath the surface, as well as the relation of the rocks of the plains to those of the mountain on the west, is illustrated in figure 9, which shows that in the uplift of the mountains the rocks have broken and those of the mountains have moved up with relation to those of the plains.

Below Pikeview the valley is cut in soft shale (the Pierre) and for that reason it is broad and shallow, and the mountains rise majestically a short distance to the west. Colorado Springs is at the point where Monument Creek joins Fountain Creek, or Fontaine qui Bouille (bubbling fountain), as it was first named by the French explorers, and the railroad runs directly down the valley to that city. Colorado Springs is the most noted health resort in Colorado and, indeed, in the entire Rocky Mountain region. It was organized by Gen. William J. Palmer as a model city on July 31, 1871, the same year that the first railroad—the Denver & Rio Grande, then a narrow-gage line—was built into the valley. It has far outgrown the ideas of its founder, however, and has become the great tourist center of the mountain region as well as an attractive residence city, a railroad point of considerable importance, and the site of Colorado College.

Colorado Springs.

Elevation 5,989 feet.
Population 30,105.
Denver 75 miles.

The name Colorado Springs is somewhat of a misnomer, for there are no large springs in the city, but it is closely connected by steam railway and by trolley with Manitou, which has springs of different kinds that have a world-wide reputation. Despite its clean, wide streets and its wealth of green lawns and shrubs and trees Colorado Springs offers little of special interest to the tourist, but it is a stopping place from which other and more interesting localities may be visited and a gateway to the attractive features of the mountains. It is built on the edge of the plains, which sweep away eastward farther than the eye can see. Few travelers who visit Colorado Springs think of the plains as worthy of their attention or as having any beauty that is at all comparable with the beauty of the mountains, but Helen Hunt Jackson, who is buried here in Evergreen Cemetery, saw beauty in all the landscapes, and she likens the plains about Colorado Springs to the wide expanse of the sea, ever changing, yet always the same.

> Between it [Colorado Springs] and the morning sun and between it and the far southern horizon stretch plains that have all the beauty of the sea added to the beauty of the plains. Like the sea they are ever changing in color, and seem illimitable in distance. But they are full of tender undulations and curves, which never vary except by light and shade. They are threaded here and there by narrow creeks whose course is revealed by slender winding lines of cottonwood trees, dark green in summer, and in winter of a soft, clear gray, more beautiful still. They are broken here and there by sudden rises of tablelands, sometimes abrupt, sharp-sided, and rocky, looking like huge castles or lines of fortifications; sometimes soft, moundlike, and imperceptibly widening, like a second narrow tier of plain overlying the first.

The continuation of the description of the country along the main line of the railroad will be found on page 53.

PIKES PEAK.

Pikes Peak is the dominating feature of the landscape about Colorado Springs. This view of the mountain, from the bank of Monument Creek, shows Engelmann Canyon and the long southern spur of the mountain up which the cogwheel road finds its way to the top. The automobile road climbs the ridge on the extreme right. Photograph by L. C. McClure, Denver.

GATEWAY TO THE GARDEN OF THE GODS.

Nature has here carved an appropriate gateway to the land of wonders that lies immediately beyond. The dark-red sandstone also serves as a frame or setting for the brilliant summit of Pikes Peak, which looms up in the distance. Photograph by L. C. McClure, Denver; furnished by the Denver & Rio Grande Western Railroad.

ONE-DAY TRIPS FROM COLORADO SPRINGS.

As most travelers on the Denver & Rio Grande Western Railroad stop here to sample the mineral waters of Manitou and to explore the peaks and canyons of the near-by mountains, the more interesting side trips that may be made in a single day will be described.

MANITOU AND THE GARDEN OF THE GODS.

The place that is first visited by most travelers stopping at Colorado Springs is Manitou, 6 miles to the west, at the foot of Pikes Peak. In order to reach Manitou from Colorado Springs the traveler must pass through the historic town of Colorado City, which sprang into existence as a result of the rush of gold seekers to the Pikes Peak region in 1859. A cluster of log cabins was built at the base of the peak, but no gold was found. In 1862 Colorado City again came into prominence, when the second legislative assembly of the Territory convened there, but after a four-day session it adjourned to Denver, the real capital of the State. It is said that the building in which the meeting was held is still standing but in a much dilapidated condition. In 1910 Colorado City had a population of 4,333; since then it has been consolidated with Colorado Springs. In the palmy days of the Cripple Creek camp it had four cyanide plants[13] in operation treating the ores, but with the decline of that camp the mills have been allowed to fall into decay. At the present time only one of them is in operation.

The town of Manitou has a permanent population (1920) of 1,357, but during the summer it has many times that number. It was originally called Villa La Font, but this name was later changed to Manitou, which is the Indian name for the Great Spirit. It is said that the Indians were familiar with the springs before the advent of the white man, and that they believed that the bubbling was caused by the breath of the Great Spirit. In Manitou there are 16 springs whose waters differ widely in the composition and quantity of the mineral matter they contain. Some of the waters are strongly impregnated with soda, others with iron and magnesia, and some contain, it is said, lithia, lime, sulphur, potash, and other

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[13] The cyanide process of treating gold ores was discovered in 1890 and is now used all over the world. It is best adapted to free-milling ores, especially after the bulk of the gold has been removed by amalgamation. The ore is first broken and ground as fine as flour. It is then carried to great vats, where the gold is dissolved by a weak solution of cyanide of potassium. After standing for several days the solution containing the gold is passed over zinc turnings, which precipitate the gold with other metals as a black slime. Similar results may be obtained by electrolysis except that the gold is obtained in a purer form on lead plates. The slime or lead plates are then treated to separate the gold from the baser metals.

minerals.[14] The principal springs are known as the Soda, Ute Iron, Ute Chief, Navajo, Geyser, Mansions, Soda-Iron, Twin Shoshone, Minnehaha, Magnetic, and Magnesia.

The second most attractive natural feature of the region is the Garden of the Gods, which can easily be reached from Manitou or from the trolley line that connects Manitou and Colorado Springs. This interesting bit of wonderland is now a part of the Colorado Springs park system, to which it was transferred in 1909 by the heirs of the late Charles Elliott Perkins with the stipulation that it should be forever kept open and free to the world.

There are two entrances to the Garden of the Gods, but the traveler should by all means approach it from the lower entrance, the one nearest Colorado Springs, for he will there get his first view of it through the celebrated "Gateway," which is in itself one of its most striking features. Plate XIX shows the great upstanding ledge of red sandstone in which the "Gateway" has been cut by a small stream. The view here shown is not that which the traveler will get from the main road but is one he could get by climbing and walking a little distance to the north before reaching the deep cut. The white rock in the foreground is a thick bed of gypsum, which contrasts strongly with the deep-red sandstone beyond.

After passing through the "Gateway" the traveler will find himself in a wonderful array of tall spires of red and white sandstone and of many fantastic forms, which have been produced by the slow weathering of the massive rock. These features are shown in Plates XX and XXI. The rocks of the Garden of the Gods are of the same general character as the upturned red sandstones between Denver and Colorado Springs, but the forms are larger and more picturesque here than they are at any other place on the mountain front. These great natural monuments look as if they had been pushed up from below the surface by some giant force, but they are really mere remnants of great masses of red and mottled rock that were long ago tilted up

[14] An analysis of Manitou table water, made by the Bureau of Chemistry of the Department of Agriculture, is as follows:

	Parts per million.
Silica (SiO_2)	47.2
Iron and aluminum (Fe+Al)	1.8
Manganese (Mn)	1.7
Calcium (Ca)	457.9
Magnesium (Mg)	79.2
Sodium (Na)	551.0
Potassium (K)	71.3
Lithium (Li)	.23
Ammonium (NH_4)	.05
Oxygen to form manganо-manganic oxide (Mn_3O_4)	0.7
Bicarbonate radicle (HCO_3)	2,664.6
Sulphate radicle (SO_4)	219.2
Chlorine (Cl)	250.0
Bromine (Br)	Small amount.
Metaborate radicle (BO_2)	Faint trace.
	4,344.88

The water is supersaturated with carbon dioxide (CO_2).

A. THE "SIAMESE TWINS."

The "Siamese Twins" are still apparently bound together by solid rock, but close inspection shows a crack along which the weather is slowly accomplishing its work of destruction. A few grains of sand may be loosened and blown away each day, and this process repeated almost indefinitely will finally sever the connection and then the columns will stand separate and distinct. Photograph by L. C. McClure, Denver; furnished by the Denver & Rio Grande Western Railroad.

B. "BALANCED ROCK."

This strange monument of nature's handiwork attracts the attention of most travelers. It was once doubtless connected with the pedestal on which it stands, but a soft layer near the bottom has been worn away until the mass seems to be ready to tumble at any moment. The red sandstone contains many pebbles and might properly be called a conglomerate. Photograph furnished by the Denver & Rio Grande Western Railroad.

GATEWAY AND SPIRES OF THE GARDEN OF THE GODS.

On approaching this wonderland through the gateway shown in Plate XIX the traveler is confronted with the great spires and needles of red sandstone standing on end as shown in this view. These monuments have been carved by the wind and weather from great beds of sandstone tilted up until they stand nearly vertical. Photograph furnished by the Denver & Rio Grande Western Railroad.

on end and then were partly removed by the dissolving action of the atmosphere. This is a slow process, but it is always in operation, and each day a few grains of sand are loosened and carried away. Under this constant attack new and picturesque forms are being produced and the old pinnacles and towers are being worn away. All these interesting monuments of the activity of weathering processes will at some time be worn down to the level of the plain, but that time will be so far in the future that the loss of the monuments need not give much concern to the present generation.

The great ledges that give to the Garden of the Gods its picturesqueness extend to the north and are again strikingly exposed in Glen Eyrie, which for a long time was the chosen home of Gen. Palmer. Plate XVII, *C* (p. 33), shows one of the more striking rocks in this well-known glen.[15]

[15] The rocks in and about the Garden of the Gods and Glen Eyrie are more fully described by Prof. George I. Finlay as follows:

Few regions in the United States offer so much to the traveler and to the student of rocks as the country about Colorado Springs. The Rocky Mountains here meet the Great Plains with a bold front. At some places, owing to faults or breaks in the beds of rock, the old, strong granite of the mountains stands in direct contact with the young, weak rocks of the plains; at others, as at Manitou and in the Garden of the Gods, the sedimentary beds are upturned in a narrow belt that offers the traveler an unusual opportunity to examine and study them. The layers of rock that compose the foothills and plains are like books on a shelf which have fallen over toward one end, so that most of them lie at low angles, although a few are nearly vertical. (See fig. 10.)

These rocks lie in distinct layers because most of them were laid down under the waters of shallow seas that from time to time invaded this part of the continent. Such seas were extensions of the Gulf of Mexico or were connected with the oceans that surrounded the continent. At one time, in the Cretaceous period, the Gulf of Mexico and the Arctic Ocean were connected by a sea that extended across North America. The continent was then reduced to a number of islands, many of which were nearly continental in size. The shallow water between them became the settling ground for the sand, mud, and gravel which the streams brought down from these great islands. Along the shores the waves were cutting away the land and reducing it to mud and sand, and strong currents were carrying these materials widely over the sea floor. After this condition had prevailed for a long time the continent was uplifted and was restored to something like its old outline. During these changes sand was consolidated into sandstone, mud into shale, and gravel into conglomer-

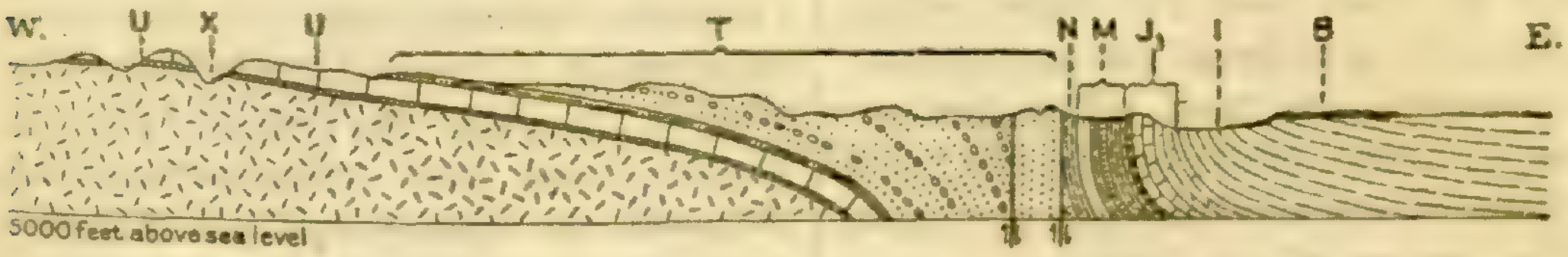

FIGURE 10.—Section through Garden of the Gods. The spires and walls of the gateway are carved in the upstanding block of sandstone, and this block is separated from the rocks on both sides by faults. For explanation of letters see Plate XXII.

PIKES PEAK.

Manitou is the place from which the start is made on the Cogwheel Road for the ascent of Pikes Peak. Pikes Peak, the highest mountain in this part of the system (14,109 feet), was named for its discoverer, Lieut. Zebulon M. Pike, who was commissioned by President Jefferson to explore certain parts of the western country acquired from France by the treaty of Paris, signed April 30, 1803, and generally known as the Louisiana Purchase. Pike had already

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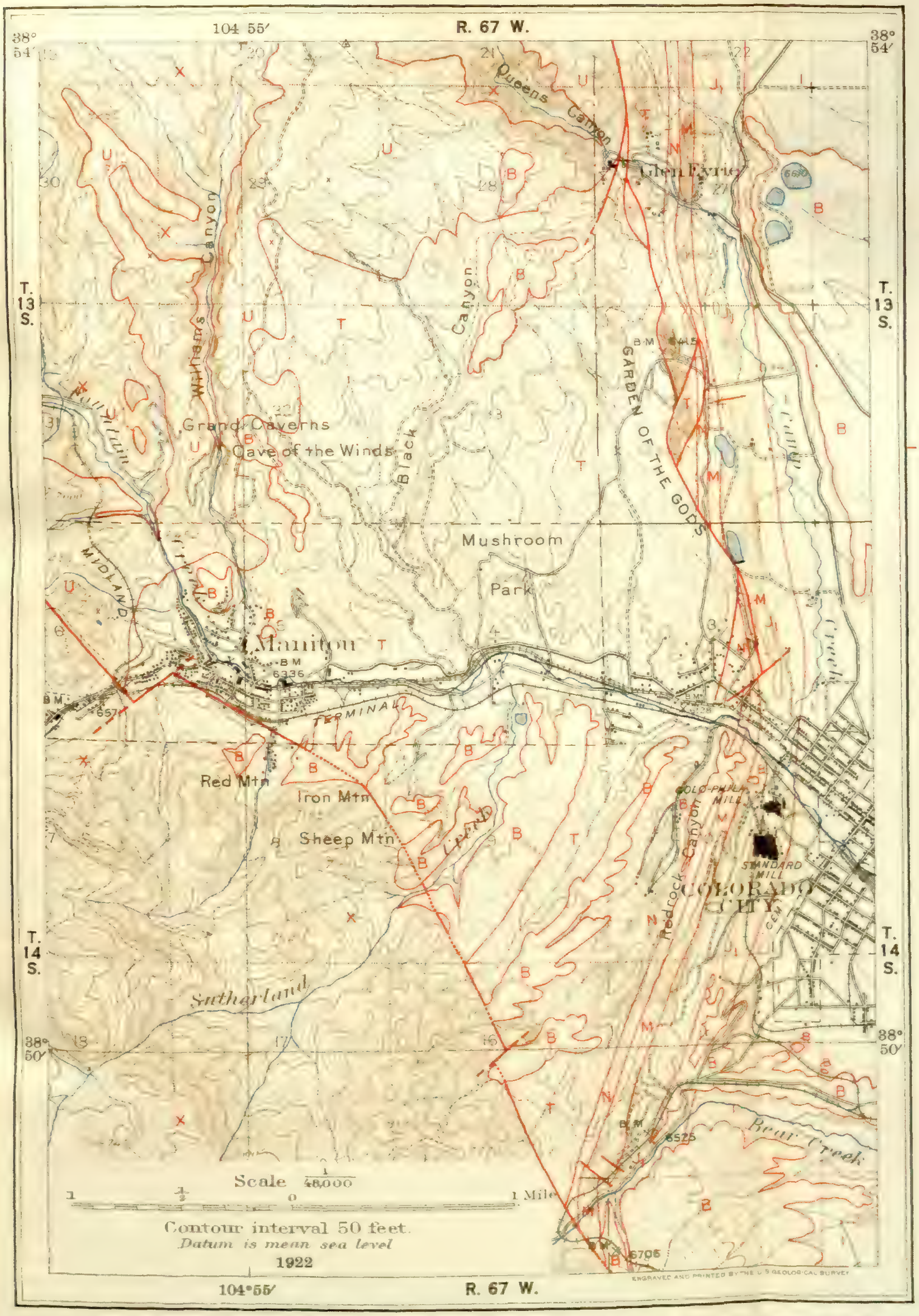
ate, all being cemented and welded together by the great weight of the layers above. In the sea limy shells accumulated in great beds and were in large part ground up by the waves and reduced to fine particles, which were cemented together by a part of their lime carbonate into beds of limestones. These several kinds of rock—shale, sandstone, conglomerate, and limestone—are the sedimentary beds which are so well represented near Colorado Springs, where their total thickness is over 10,000 feet. These beds of rock were not originally vertical or inclined but lay horizontal, and it was the uplift of the mountains, which occurred long after they had been formed, that disturbed them. Their edges are now exposed all the way from Manitou to Austin Bluff, east of Pikeview. The oldest of these beds are those which lie upon the granite of the mountains; the youngest are those which are exposed in Austin Bluff and beyond; and the beds of intermediate age are those in the Garden of the Gods.

The formations into which the sedimentary rocks of the Colorado Springs region are grouped by geologists and the names of the geologic periods in which they belong, as determined by the study of their fossils, are shown on sheet 2 (opposite p. 84) and in the general section on page 11. The term formation is generally applied to a distinctive bed or a series of distinctive beds of rock, such as sandstone, shale, or limestone, that were formed continuously or in close succession during a certain period of geologic time, or to a group of beds that are of about the same geologic age. It is thus frequently applied to such an assemblage of beds as may be grouped together as a unit for convenience in mapping. The deposits made in a single geologic epoch or period are usually represented by several formations. In this region the Upper Cretaceous epoch, for instance, is represented by eight formations, though other periods are each represented by only one formation. Between the Manitou limestone and the shale at the base of the Fountain formation there are no representatives of the rocks that were formed elsewhere during the Silurian and Devonian periods. Nor is there any rock to represent the earliest division of the Carboniferous period. The absence of these beds means either that during these long periods of time the Colorado Springs region was dry land, upon which no material was being deposited, or that the rocks then deposited there were later worn away. Between the Lykins and the Morrison formations no representative is found of the Triassic period, whose rocks constitute another of the geologic systems.

Not all the sedimentary rocks of the Colorado Springs region were laid down on the sea floor. The Dawson arkose, for instance, at the top of the column, was spread out on the land by the many eastward-flowing streams, which brought quantities of disintegrated granite and gravel down from high lands on the west. As these streams shifted from side to side over the country they spread gravel somewhat evenly over the slope until they had thus deposited considerably more



EXPLANATION

B	Gravel on mesas and terraces	Pleistocene and Tertiary
I	Fox Hills sandstone and Pierre shale	Upper Cretaceous
J_1	Colorado group	Upper Cretaceous
M	Dakota sandstone Purgatoire formation	Lower Cretaceous
N	Morrison formation	Cretaceous?
T	Lykins formation Lyons sandstone	Carboniferous (*Permian? and Pennsylvanian*)
U	Millsap limestone	Carboniferous (*Mississippian*)
	Fremont limestone Harding sandstone Manitou limestone	Ordovician
	Sawatch sandstone	Cambrian
X	Granite	Pre-Cambrian
	Fault	

GEOLOGIC MAP OF MANITOU AND THE GARDEN OF THE GODS, COLORADO

By G. I. Finlay

made a trip to the source of the Mississippi when he was directed to explore what was then known as the "Southwest." He and his party left Missouri in July, 1806, and went across the country to the Arkansas and up that valley to the site of Pueblo. At the mouth

than a thousand feet of coarse material. The Fountain formation is similar to the Dawson arkose, and much of it was no doubt similarly deposited. The Lykins formation is made up of beds which were laid down in land-locked bodies of water in a region that had an arid climate. The Laramie formation is made up of beds of sandstone and shale between which there are layers of coal that represent accumulations of vegetal matter in swamps. When a tree dies in the forest it quickly decays, but when it falls into a pond of water, as in a swamp, the water protects it in a great measure from decay, so that its carbon is stored up and accumulates as coal.

Colorado Springs is built on the nearly horizontal Pierre shale. The road from Colorado Springs to Manitou leaves this shale just west of Colorado City and in the succeeding 3 miles crosses the steeply upturned beds of the Cretaceous formations. Beyond Quarry Spur it passes over the Fountain beds, which underlie Manitou. These relations will be understood from a study of the map shown in Plate XXII and the cross section forming figure 10.

On leaving Manitou a walk of less than a mile up Ute Pass as far as Rainbow Falls takes one past the sedimentary rocks into the granite. On either hand, resting on the granite, are the lowest white layers of the Sawatch sandstone, of Cambrian age, the oldest sedimentary rock in this region. The contact between the granite and the sandstone is everywhere so remarkably even as to indicate clearly that before the sand which formed the sandstone was deposited the granite had been worn down to a smooth surface or a nearly perfect plain. About 50 feet above the granite the dove-colored Manitou limestone (Ordovician), over 200 feet thick, succeeds the sandstone and forms the bulk of the ridge between Ute Pass and Williams Canyon. In Williams Canyon (Pl. XXIII) the walls are composed of the same two formations, overlying the granite.

The Cave of the Winds, in the Manitou limestone, compares favorably with the Mammoth Cave of Kentucky and the Luray Caverns of Virginia, though it is by no means so large. The limestone in which the cave has been excavated was honeycombed by the solvent action of rain water, which sank into it along cracks and passed through it in small streams. Later the streams left the caverns which they had made, and the dissolved lime carbonate in the water that dripped from the cracks in the roofs of the cavern produced icicle-shaped forms known as stalactites. Water dropping on the floors of the caves similarly built up stalagmites. Queens Canyon, 3 miles north of Colorado City, is in the same formation.

East of Manitou and north of the railroad track there are fine exposures of the Fountain formation, which stretches over to the Garden of the Gods. The red rock series—made up of the Fountain formation, the Lyons sandstone, and the Lykins formation—is about 5,000 feet thick. Near Manitou the Fountain beds dip 11° E. In the Garden of the Gods they were tilted until they stand vertical, and in the intervening ground they stand at intermediate angles. (See fig. 10.) Interesting erosion forms may be seen in the Fountain formation in Mushroom Park and just west of the great masses of Lyons sandstone in the Garden of the Gods. Some of these forms rise 200 or 250 feet above the adjacent ground.

of Purgatory Creek he caught sight of Pikes Peak, far to the north. Pike, in his journal, calls it the "Grand Peak." He was fired with

Just to the east of the gateway to the Garden of the Gods the gypsum layer of the Lykins formation is prominent. (See Pl. XIX.) This gypsum undoubtedly crystallized out of a land-locked body of sea water which had been reduced by evaporation in an arid climate to a state of supersaturation. Gypsum, a mineral so soft that it can be scratched by the finger nail, is used in making wall plaster and as a fertilizer. The Morrison formation, which is made up chiefly of maroon and green limy shale, is best seen near Colorado City in the railroad cut just east of Quarry Spur. This formation, which generally extends along the Rocky Mountain Front, has yielded many bones of huge reptiles, such as the Ceratopsia. One skeleton was found in the Garden of the Gods. This is the same band of rock in which remarkable reptilian remains were found west of Denver and north of Canon City. (See Pl. XXXII, *B*, p. 70.)

To observe the outcrops of the formations of Cretaceous age as high in the column as the Niobrara formation it is necessary to leave the railroad track just west of Colorado City and climb about 100 feet to the level of the gravel bench. These outcrops form perfectly straight hogback ridges between Fountain Creek and Bear Creek, and the beds in them stand nearly vertical. The western hogback is made up of Dakota sandstone and the Lower Cretaceous rocks that are associated with it. The eastern hogback carries along its crest the sandstone member of the Carlile formation and the overlying Niobrara limestone, which are also well exposed.

The traveler should visit the mesa, the large mass of gravel overlying the Pierre shale in the V between Monument and Fountain creeks. This is but one of many remnants, all sloping away from the mountains at much the same height, of a great deposit of gravel which has been cut through by such streams as Fountain Creek. One who restores in his mind's eye from mesa to mesa the gravel plain represented by the surface of these remnants can get an idea of the former extent of this stream-laid gravel, which was spread out by streams flowing from the mountains, and can understand the mode of formation of the Dawson arkose, which was similarly laid down millions of years earlier than this gravel.

To the south the ragged crest of Cheyenne Mountain rises more than 2,000 feet above the sedimentary beds at its eastern base. This sudden change in the surface features is due to the different rate of weathering of the sedimentary beds and the great granite mass, which was upraised along the Ute Pass fault for more than a mile and at the same time thrust forward about 4 miles. By this faulting movement the sedimentary rocks between Manitou and the southern end of Cheyenne Mountain were sheared off as shown in figure 13 (p. 53). The detached masses of sedimentary rock that once lay upon the upthrown block of granite were carried up with it and were long ago worn away and lost by erosion. Plate XXIV, *B*, and figure 13 show the Ute Pass depression, which marks the fault-line break where it continues northwestward through the granite of the Front Range. This is the greatest fault or dislocation of the rocks in the Colorado Springs region. As these faulting movements took place in geologically recent time the Rocky Mountains, which were brought into being by them, are therefore recent features in the geologic sense. They were probably raised up after the deposition of the Dawson arkose.

WILLIAMS CANYON, MANITOU.

The rugged scenery about Manitou is well illustrated by the view, which also shows the good roads that make all the interesting places accessible. Photograph by L. C. McClure, Denver.

A. PIKES PEAK AND THE ROCKY MOUNTAIN PENEPLAIN.

The appearance of Pikes Peak depends largely upon the point of view and the setting. From Colorado Springs it seems to be a mass of mountains piled one above another until it culminates in the main peak. Viewed from the north, as in this picture, it is clearly a single mountain mass standing on a plain (Rocky Mountain peneplain) left by the erosion of the surrounding rocks. The plain has an elevation of about 9,200 feet, and this peak rises nearly 1,800 feet above it. Photograph by G. B. Richardson.

B. UTE PASS.

This view is taken from a point near the falls, looking south to Manitou, which may be seen in the distance. Above the fine automobile road over which the traveler passes on his way to the summit of Pikes Peak are beds of quartzite (hardened sandstone) resting directly on the granite. This unusual contact is not due to a fault but to the fact that the sand was deposited on the granite surface which then formed the floor of the sea. Photograph furnished by the Denver & Rio Grande Western Railroad.

the ambition to climb it, so he started off from his camp at the site of Pueblo, on Arkansas River, supposing that he could easily reach its summit and return in the course of a few days. He was not accustomed to the clear air of the mountains and did not realize that the peak was 45 miles distant in an air line and about 9,500 feet above him. The party traveled directly toward the peak, and finally, on November 27, 1806, after great hardships, they reached the summit of the plateau, at an altitude of probably 9,000 feet, far south of the peak. The mountain was covered with snow, and they saw that they were but little more than halfway to the top. As they were not prepared for such cold weather, they suffered severely and concluded that it was then impossible to reach the summit. They returned as they came and then pursued their way up the river toward the site of Canon City.

The first person to climb to the summit of Pikes Peak was Dr. Edwin James, botanist, geologist, and surgeon of Maj. Long's expedition, in 1820.[16] On account of this ascent Maj. Long named the mountain James Peak, and it was called by this name for a number of years. Eventually, however, the name of its discoverer, Pike, was given to the mountain, and it is now firmly fixed as the most appropriate one that could have been chosen.

Pikes Peak stands at an altitude of 14,109 feet, or more than 1½ miles (7,920 feet) above Colorado Springs. Its summit may be reached by the Manitou & Pikes Peak Railway, better known as the Cogwheel Road, or by automobile over the road recently completed from Cascade to the top. The first part of the Cogwheel route

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[16] The Long expedition came to this region over practically the same route that the traveler on the Denver & Rio Grande Western has followed south from Denver. Maj. Long camped at the mouth of Monument Creek (Colorado Springs) to allow Dr. James an opportunity to climb the mountain called by Pike the "Grand Peak." On July 13, 1820, Dr. James and two companions started for the mountain. After dining at the "boiling spring" (Soda Spring at Manitou) they began the ascent of the mountain, taking with them only a single blanket. They camped on their way up, probably before they got to the timber line, and spent a very uncomfortable night. After much hard climbing the party reached the summit about 4 o'clock in the afternoon. In their descent they lost their way and were obliged to spend another night on the mountain side without food or blankets. On the morning of July 15 they continued their descent to the boiling spring, where Dr. James entered the following note in his journal:

"A large and much frequented road passes the springs and enters the mountains, running to the north of the peak. It is traveled principally by the bisons; sometimes also by the Indians, who penetrate here to the Columbia."

Evidently Ute Pass was used as a thoroughfare long before the white man was familiar with the region. The geologic cause of this low pass is stated on page 40.

through Engelmann Canyon, which is nearly filled with large granite boulders, is very picturesque. The small stream tumbles over the great blocks of rock in continuous cascades, and overhead and around is the deep green of the native forest. Near the upper end of the canyon is the intake of the main that supplies Colorado Springs and Manitou with pure, cold mountain water. The water supply of these towns is derived not only from this particular valley but is gathered by a system of tunnels and canals from a number of rocky basins whose natural outlet is to the west.

After passing through the rough part of Engelmann Canyon the road emerges onto a comparatively level terrace of the mountain side at an elevation of about 9,000 feet. On this terrace the ancient glaciers that came down from the high peak above dumped great quantities of loose fragments of rock in ridges that are called moraines. The ice has disappeared, but the moraines still testify to the existence and the extent of the ice. The most conspicuous moraine to be seen from the Cogwheel Road is that which encircles and holds in place Lake Moraine, on the left. The moraine had formerly been breached by a stream, but it has been artificially restored to its original condition, and it now holds a lake of considerable size.

The surface of the mountain above timber line consists of granite, which is bare except where it is covered by snow. After circling around a long spur that projects to the south the train arrives at the summit. On the east are Colorado Springs and Manitou, which look like small villages or gardens spread at the foot of the mountain, and still farther east are the plains, which stretch like a carpet as far as the eye can see. On the west and southwest the mountains roll like the billows of the sea far into the hazy distance. The Sangre de Cristo and the great Sawatch ranges tower like giant rollers high above the others, as if the sea had been consolidated at the very moment of its greatest agitation. On the north is the Rampart or Front Range, but in this direction, instead of rugged mountains, one sees only a gently undulating plateau, which from this great height looks much like the plains on the east except that it is dark with a growth of evergreen trees.

To the traveler who is unfamiliar with high altitudes one of the most striking features here is the effect of weathering on the rocks. The summit and the slope on the southwest side for some distance down are covered with blocks of granite that have been broken from the massive rock that forms the top of the mountain. The rocks on the summits of all high peaks are broken and thrown down in the same way, evidently through the rigors of the climate in such high and exposed places. The warm rays of the sun during the

day expand the rocks and melt some of the snow, and the water so formed sinks down in cracks and crevices and during the ensuing night freezes. The expansion and contraction of the rocks due to changes in temperature and the freezing of water in joints and fissures soon break to pieces even the most massive granite, as shown on the summit of the peak.

The first railroad that was projected up Pikes Peak was an ordinary steam road. It was planned to follow a circuitous route with a maximum gradient of 250 feet to the mile and to reach the summit in a distance of 30 miles. Construction was started in 1884, and about 8 miles was graded when the scheme failed through lack of financial support. Surveys for the present road were begun in 1888, and the golden spike was driven on October 20, 1890. The maximum gradient of this road is 1,320 feet to the mile, and the length is 9 miles.

The automobile road reaches the same point on the summit that is reached by the Cogwheel Road. The length of the road is 18 miles; its average grade is 370 feet to the mile, and its maximum grade is 554 feet. The view from the automobile road is even more impressive than that from the Cogwheel Road, for, owing to the numerous bends, the traveler can see the ever-widening landscape on all sides. The route passes through Manitou and up the narrow defile of Ute Pass, at first over the edges of the eastward-dipping quartzite and then over the underlying granite. The road as well as the contact between the quartzite above and the granite below is well shown in Plate XXIV, *B*. At the village of Cascade the new road turns and climbs the west wall of the canyon, and as it rounds the point directly above Cascade the traveler can look down the pass to Manitou, far in the distance. The road follows Cascade Creek for some distance in a canyon hemmed in by granite walls, but these grow less and less steep as the automobile moves on until finally the road passes by a gentle grade from the head of the valley to the divide between Cascade and Catamount creeks. At this height, about 9,250 feet, the traveler gets a wide view, particularly to the north, and he may note that the sky line, as shown in Plates XV, *A*, and XXIV, *A*, is as level as that of the plain about Colorado Springs, except that here and there low knobs rise island-like above the level surface, and far away in the hazy distance he can just make out the blue outline of Tarryall and Mosquito ranges. Could the traveler, however, cross the apparently level plain at which he is looking he would find that it is smooth only in appearance from a distance, for it is really cut up into numerous ravines much like the one followed by the automobile road. Another feature which the traveler will probably notice on the

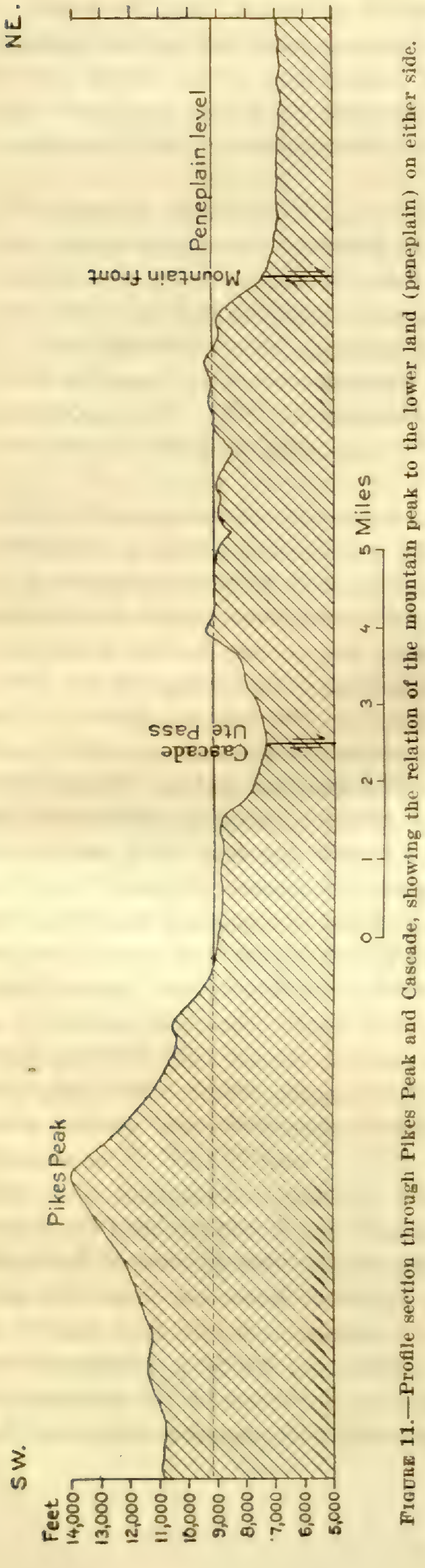

FIGURE 11.—Profile section through Pikes Peak and Cascade, showing the relation of the mountain peak to the lower land (peneplain) on either side.

surface of this plain is the deep and perfect disintegration of the granite rock which composes all this country. No ledges of rock can be seen, and the soil is made up largely of small fragments of granite broken up by the action of the weather. This even surface is well shown in Plates XV, *A* (p. 31), and XXIV, *A*, and its relation to Pikes Peak is shown in figure 11.

This plateau can be traced northward at least as far as Denver. It is the result of long exposure to the action of the weather and the cutting of the streams when the entire region was at a much lower level than it is to-day—so low, in fact, that the streams could cut no lower—and it remained in this position so long that most of the hills and other inequalities of the surface were worn away and the region was reduced to a plain as truly as the country about Denver and Colorado Springs is a plain to-day. That was long, long ago, as man measures time, even before man was there to see any of the operations that produced the change.

Then came a slow but steady uplift of the mountain region and probably also of the plain, until the land reached its present height above sea level. Such an uplift accelerated the streams, and they soon cut deep canyons—such as Ute Pass and the canyon of Cascade Creek—in the surface of the plateau, until to-day it is level only as one looks across broad tracts of its old surface and at a distance so great that the details fade and the plain looks as it once did before

the uplift came. At that time, owing to the fact that the rocks of Pikes Peak are more resistant than those of other parts of the region, the mountain stood nearly 5,000 feet above the surface of the plain, just as to-day it stands nearly 5,000 feet above the surface of the plateau.

From the plateau the slopes of the mountain above appear to be unscalable by a road, and it is only by constant turning and looping back upon itself that the road finally reaches what appears from below to be the summit but what is really a long spur of the mountain that branches off to the northwest. The northern slope of this spur, up which the traveler came, is very steep, but the opposite slope is so gentle that it scarcely can be considered mountainous. The difference in the appearance of the two slopes is well shown at a place called "the Bottomless Pit." Here the traveler may stand in his automobile and gaze down on the north into a jagged pit about 1,700 feet deep, whereas on the other side the slope is very gentle. As the rocks are the same on both sides of the ridge there must be some cause other than rock texture for this great difference in appearance. Geologists recognize that the steep, jagged slopes on the north side are the result of the action of moving ice, but the traveler may inquire: Where is the ice? The climate here is now so mild that practically all the snow which falls in the winter is melted away during the succeeding summer, but ages ago the climate of all the United States was much more severe than it is to-day, and large glaciers were formed on almost every mountain peak. The most favorable place for the snow to accumulate was on the north and east sides, for it was not blown away by gales coming from the west, and it was protected from the heat of the sun more than it would have been on the other sides. Thus the glaciers were restricted to the north and east sides, or at least they were more numerous and larger there than they were on the other sides.

In that far-off time fairly large glaciers lay on the side of Pikes Peak, and they gouged out great amphitheaters or cirques, as they are generally called, in the mountain side. In this manner the original more gentle slope was converted to nearly vertical walls. The rocky material that was removed from these cirques was carried down by the glacier and deposited at its extremity as a ridge or moraine or was washed down Fountain Creek. If the traveler wishes to see how steep are the cliffs produced by a glacier he has only to walk to the end of the Cogwheel Road and look down a thousand feet or so into the rocky basin that the ice has cut.

CRIPPLE CREEK BY WAY OF THE "SHORT LINE."[16a]

The trip from Colorado Springs to Cripple Creek over the "Short Line" affords the traveler an opportunity to see some fine and extremely diverse mountain scenery and to visit one of the active gold-mining districts of Colorado.

The route extends directly west from Colorado Springs, past some of the big mills that were built to reduce the Cripple Creek ores, and then passes up along the right side of Bear Creek canyon. Here the sedimentary rocks are upturned so steeply that they stand on edge and make great hogbacks across the country. (See p. 40.) The train passes the limy outcrop of the Niobrara and then goes through a projecting point of the Dakota sandstone. Just beyond this ledge the railroad crosses Bear Creek canyon and swings back on the other side. At the point where it crosses the canyon the Dakota sandstone abuts "end on" against the granite of the mountain. Such a contact is not normal, and it means that the two diverse kinds of rocks were brought into contact by a great break, or, as the geologists call it, a fault, in the rocky crust of the earth, the granite having been thrust up out of place until it rested against the broken edges of the beds of sandstone. This fault is the one that separates the granite from the red sandstone a few rods below the station of the Cogwheel Road in Manitou, and its course is marked by Ute Pass, which it produced and through which the Midland Terminal Railway (formerly the Colorado Midland) finds a way to Woodland Park. South of Bear Creek the fault is marked by the base of the mountain, and to it is due the abrupt change from steep mountain slope above to flat-lying plain below.

The "Short Line" climbs the mountain front, gradually attaining higher and higher altitudes, until it rounds Point Sublime, from which the traveler can look down nearly a thousand feet into North Cheyenne Canyon. The view from this point is shown in Plate XXV, *A*. Beyond this point the railway winds in a serpentine course around spurs and ravines as it adjusts its course to the contour of the slopes. But here and there a mountain spur is so large or so rugged that the cost of grading the roadbed around it would be very great, so the train plunges through the spur by a tunnel that reaches its very core, and in some places it crosses on high trestles rushing torrents that cascade down the steep granite walls, as shown in Plate XXVI. In this manner the train circles around the slopes

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[16a] At the time this guidebook goes to press the Cripple Creek Short Line is not in operation, no trains having been run on it for two years. It is hoped, however, that operation will be resumed and that the traveler will have the opportunity of taking the trip here described. Otherwise his best substitute is a trip by automobile to this world-renowned camp.

A. POINT SUBLIME.

The Cripple Creek Short Line, after climbing the east front of the mountain to an elevation of 1,000 feet, turns abruptly into North Cheyenne Canyon. From this turn, called Point Sublime, the traveler may look down nearly 1,000 feet into the rocky canyon and far out over the wide expanse of plains to the east. Photograph by L. C. McClure, Denver; furnished by the Cripple Creek Short Line.

B. DEVILS SLIDE.

The Cripple Creek Short Line curves around the heads of ravines, tunnels through the projecting spurs, and passes great bare rounded granite masses that have received fanciful names. The domelike mass shown in this view is known as the Devils Slide. Photograph furnished by the Cripple Creek Short Line.

SILVER CASCADE.

When this photograph was taken but little water was flowing over the rocks, but earlier in the season, when the snow on the mountain is melting, the water leaps from ledge to ledge and slides down the rocky slopes in sheets of lacy foam. The smooth, round slopes and mountain tops show clearly how readily the most massive granite softens and decays. Photograph by L. C. McClure, Denver; furnished by the Cripple Creek Short Line.

of North Cheyenne Canyon far above the rugged scenic part and then tunnels through the dividing ridge and circles around the slopes of South Cheyenne Canyon, all the time climbing so as to cross the divide at its head.

In this long climb the traveler may obtain many beautiful views of rugged mountain slopes covered with a stately forest of evergreen trees, of foamy cascades that plunge down gulches and ravines, of great bare rock slopes, such as the one shown in Plate XXV, *B*, and of far-off Colorado Springs, spread out on the level prairie like a miniature garden.

The crest is passed at the station of Summit (altitude 9,913 feet), and the train then begins the descent of the west side. This side is much less steep than the one up which the train has laboriously climbed, and along it the roadbed winds about from one valley to another as it crosses the headwaters of a number of mountain streams. Many of the valleys of these streams contain ranches, but some are mere gorges in the rugged granite, such as is shown in Plate XXVII, *B*.

The train finally arrives at Goldfield Junction, in the midst of some of the largest gold mines of the Goldfield district (Pl. XXVIII, *A*). If the traveler wishes to see the big mines and mills to the best advantage he should here transfer to the "High Line" trolley, which carries him around mountain tops, among mines, mills, and dump heaps of waste rock, and finally lands him in the once famous town of Cripple Creek, the center of one of the best-known mining districts in Colorado. Returning he can see most of the low-lying part of the Cripple Creek district from the steam cars, especially the great mines at Victor and Goldfield. The district was prospected at several periods, but it was not until the autumn of 1890 that Robert Womack discovered gold in place at what is now the Gold King mine, or in the flank of Poverty Gulch, just southeast of the town of Cripple Creek. Since then the district has produced more than $300,000,000 in gold, and its present yield is about $350,000 a month. A more detailed account of the discovery, development, and present condition of the district is given below by F. L. Ransome.[17] Further information concerning the district is given in the Geological Survey's Professional Paper 54.

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[17] The Cripple Creek district is one of the most interesting, productive, and thoroughly studied gold districts in the United States. The historic rush of prospectors to Pikes Peak in 1859, with its well-known slogan of "Pikes Peak or bust," resulted in no important discoveries and is significant rather because it was the first determined attack upon the wilderness than because it had any direct connection with the history of Cripple Creek. It was not until 1874 that the region adjacent to Cripple Creek began to attract the attention of prospectors. The report that gold had been found

SOUTH CHEYENNE CANYON.

One of the most romantic as well as most beautiful places in the region about Colorado Springs is South Cheyenne Canyon, immortalized by Helen Hunt Jackson and for some years the resting place of her body.

This beautiful canyon lies 3 miles southwest of Colorado Springs and can easily be reached by trolley or private conveyance. The

near Mount Pisgah drew a number of men to that locality. A few loose fragments of ore were picked up on the surface, and the Mount Pisgah mining district was organized, but as no valuable deposits were uncovered the district was gradually deserted. There was a brief renewal of activity in 1884, caused by the reported discovery of rich placer deposits near Mount Pisgah, but the supposed discovery appears to have been fraudulent, and the grassy hills of the Cripple Creek region, now thoroughly discredited in the eyes of mining men, were given over to the grazing of cattle. For a long time the only habitation in the region was the log house of Bennett & Myers's Broken Box ranch, which still stands in the southern part of the town of Cripple Creek. A few prospectors continued to work in the district and met with some success, but the event that was destined to transform a lonely cattle ranch into one of the greatest gold-producing districts of the world was the discovery by W. S. Stratton, on the Fourth of July, 1891, of the Independence vein, on what is now the site of Victor.

Notwithstanding the fact that many mining men of capital and experience looked askance at what they regarded as another Cripple Creek bubble, the development of the district was extraordinarily rapid. Before the opening of the spring of 1892 the hills swarmed with prospectors, and on February 26 the town of Cripple Creek was incorporated. The main route into the district at this time was from the north, by wagon road from Florissant.

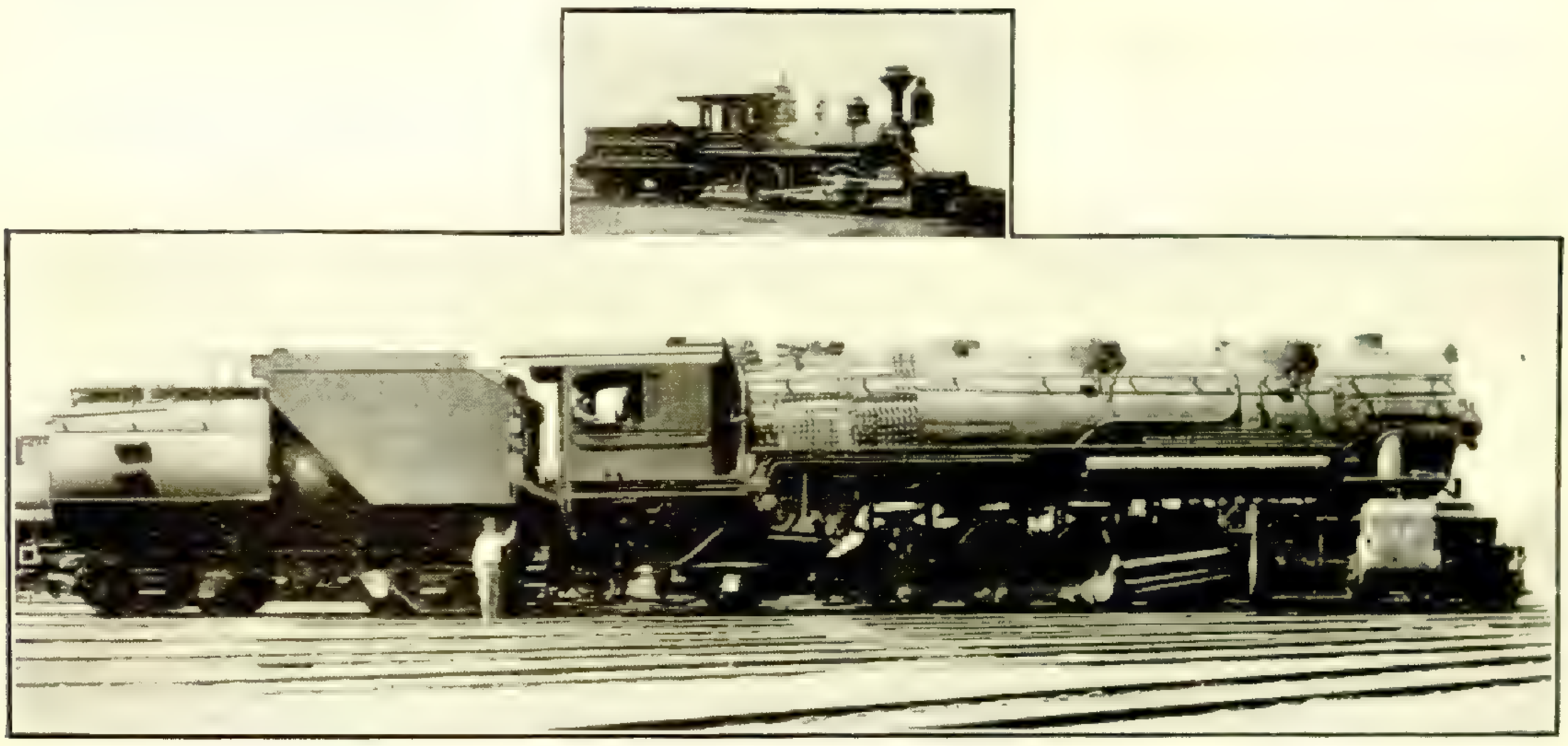
In the autumn of 1893 the list of producing mines included the Blue Bird, C. O. D., Dead Pine, Doctor, Eclipse, Elkton, Gold Dollar, Granite, Ingham, Logan, Mary McKinney, Moose, Morning Glory, Portland, Raven, Stratton's Independence, Strong, Tornado, Zenobia, and many other well-known properties. (See Pl. XXVIII, *B*.)

The Colorado Midland Railway (now the Midland Terminal), which connects Cripple Creek with Colorado Springs by way of Divide, was completed December 16, 1893, and the Florence & Cripple Creek Railroad was opened to traffic July 2, 1894.

The year 1894 is memorable on account of a strike, during which the miners resorted to arms, property was destroyed, and lives were lost. In spite of these disturbances the development of the district made notable strides, and the Independence mine in particular, which at this time was only 70 feet deep, revealed bodies of ore that were the marvel of the camp.

In 1895 the Portland mine had reached a depth of 600 feet and the Independence a depth of 470 feet. The Independence was the most profitable mine in the district, and Stratton, now a rich man, began to buy outlying property. Considerable excitement was caused by the discovery of the remarkably rich ore shoots in the Moose, Raven, and Doctor mines on Raven Hill. About this time several of the mines reached water and had to begin pumping.

During the next few years the number of producing mines continued to increase, and in 1900 the district made its maximum output, $18,000,000. The Victor and Isabella mines were highly productive up to 1898 and 1900, re-



THE OLD AND THE NEW IN RAILROADING.

That the term "baby railroad," applied in derision to the Denver & Rio Grande when it was first put in operation, was not inappropriate is shown by a comparison of the first locomotive used on the road with a standard freight locomotive of the present day. Photographs on the same scale furnished by the Denver & Rio Grande Western Railroad.

CATHEDRAL ROCKS.

Curious forms which the granite assumes in weathering are shown in the Cathedral Rocks, which the train passes a short distance west of the summit. These forms are produced by the scaling (exfoliation) of the granite in curved layers resembling the layers on an onion. Photograph furnished by the Cripple Creek Short Line.

A. BULL HILL, CRIPPLE CREEK DISTRICT

This view in the heart of the district shows how thoroughly the rocks near the surface have been prospected for gold. Most of the prospects have yielded little or no return, but some have been developed into large mines. Photograph furnished by the Cripple Creek Short Line.

B. ANACONDA AND MARY McKINNEY MINES.

There is scarcely room between the mine dumps for the towns in the Cripple Creek district. Photograph furnished by the Cripple Creek Short Line.

canyon (see Pl. XXIX) is attractive not only on account of the beauty of its magnificent granite walls—a miniature Yosemite—but also because the cut in the massive granite is the enduring record of events that took place long before the white man saw this country and in all probability before man existed on the globe. All the mountains, hills, valleys, and plains constitute records of similar events, but here the record is so clear and distinct that anyone may decipher it after he has had a slight training in the alphabet Nature uses.

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spectively, and shipped large quantities of very rich ore. Four long drainage tunnels, the Chicago, Good Will, Ophelia, and Standard, were begun about this time. Another notable event of the year 1900 was the sale of Stratton's Independence, the most famous mine in the district, to the Venture Corporation (Ltd.), of London, for $10,000,000.

In 1901 the Colorado Springs & Cripple Creek District Railway ("Short Line") was built into the district. About this time many of the larger mines, having worked down to the water surface determined by the outflow through the Standard tunnel, were again compelled to seek deeper drainage. A drainage commission was formed, subscriptions were collected, and in 1903 the El Paso tunnel was begun. Connection was made with the El Paso mine, under Beacon Hill, in the autumn of the same year.

Early in 1903 a strike was ordered by the Western Federation of Miners in all mines shipping ore to certain reduction works in Colorado City, and for about two years the district was the scene of many deeds of violence.

With the deepening of the mines the El Paso drainage tunnel became inadequate, and in May, 1907, the Roosevelt tunnel was started from Cripple Creek canyon, about 5 miles below the town, at an elevation of 8,033 feet above sea level, or 750 feet below the El Paso tunnel. This tunnel reached the porous volcanic rocks and began to drain the mines about the end of 1910.

The Cripple Creek hills lie near the eastern border of a lofty and deeply dissected plateau, which slopes gently westward for 40 miles from the southern end of the Colorado Range, dominated by Pikes Peak, to the relatively low hills connecting the Mosquito and Sangre de Cristo ranges. The prevailing rocks of this plateau are granites, gneisses, and schists. During Tertiary time volcanic eruptions broke through these ancient rocks at several points and piled tuffs, breccias, and lavas above the uneven surface of the plateau. The eruptive rocks of the Cripple Creek district are the products of one of the smaller isolated volcanic vents of this period, a vent that erupted phonolite, a kind of rock that does not occur elsewhere in this general region. The most abundant products of the Cripple Creek volcano now preserved are tuffs and breccias, which cover a rudely elliptical area in the center of the district about 5 miles long from northwest to southeast and about 3 miles wide. The main breccia mass fills what once must have been a steep-walled chasm of profound depth. From the Conundrum mine, on the western slope of Gold Hill, to Stratton's Independence mine, on the south slope of Battle Mountain, the old granite walls plunge steeply down, with slopes which range in general from 70° to vertical and which in places actually overhang the breccia. This entire southwest contact represents a part of the wall of the great pit formed by the volcanic explosions that produced the breccia. In most of

South Cheyenne Canyon and the form of the mountains in this part of the State indicate to the geologist, as already explained, that at a time long, long ago this part of the earth's crust was much nearer sea level than it is now. The mountains of Colorado were not then the magnificent spectacles they are to-day but were more like the Appalachians. Pikes Peak of that time was probably not more than 5,000 or 6,000 feet above sea level, and the plains reached back many

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the other parts of the contact the walls are also steep. The general conclusion reached is that a tremendous volcanic explosion blew a great hole in the older rocks of the plateau. This hole was subsequently filled, perhaps partly with the fragments produced by the first explosion, including bits of granite and schist and pieces of the trees that were growing on the plateau

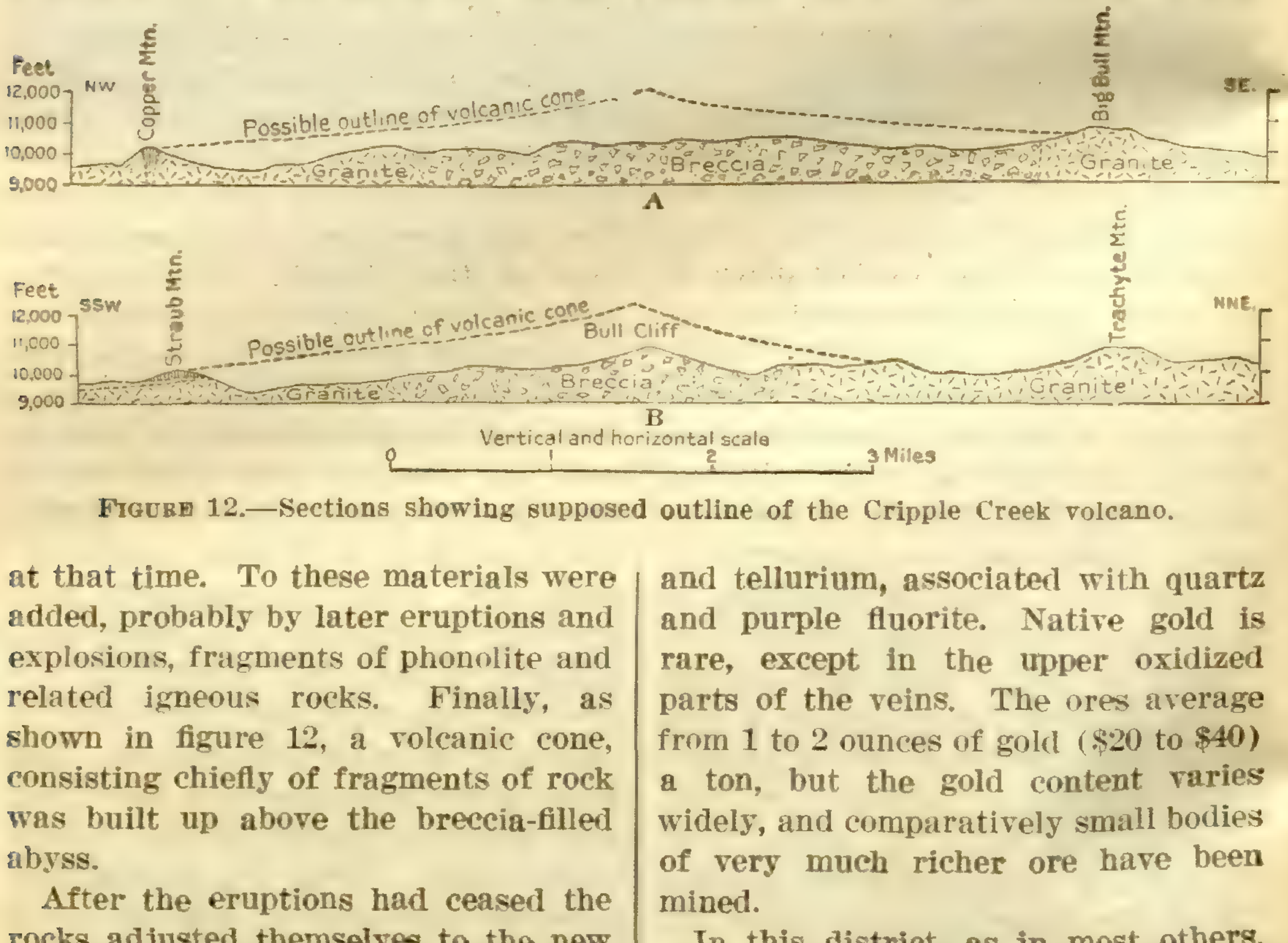

FIGURE 12.—Sections showing supposed outline of the Cripple Creek volcano.

at that time. To these materials were added, probably by later eruptions and explosions, fragments of phonolite and related igneous rocks. Finally, as shown in figure 12, a volcanic cone, consisting chiefly of fragments of rock was built up above the breccia-filled abyss.

After the eruptions had ceased the rocks adjusted themselves to the new conditions. Cracks were formed in them and in these cracks the gold ores were deposited by hot solutions that rose from deep volcanic sources. Rain and streams gradually wore away the cone and exposed the veins thus formed, which the keen eyes of prospectors afterward detected.

The gold ores of Cripple Creek occur partly as narrow veins or as groups of closely spaced narrow fissures (sheeted zones) and are partly distributed more or less irregularly through masses of altered granite near fissures. Neither form of deposit is conspicuous at the surface, and only experienced prospectors would have found them. The gold is present chiefly in the pale brass-yellow mineral calaverite, a combination of gold and tellurium, associated with quartz and purple fluorite. Native gold is rare, except in the upper oxidized parts of the veins. The ores average from 1 to 2 ounces of gold ($20 to $40) a ton, but the gold content varies widely, and comparatively small bodies of very much richer ore have been mined.

In this district, as in most others, the ore is not uniformly distributed along the veins but is limited to what are known as shoots and occurs particularly where veins cross one another. Some of these shoots, such as the one found in the Cresson mine a few years ago, have been extraordinarily rich, but the larger mines, like the well-known Portland, depend mainly upon large shoots of ore of

PILLARS OF HERCULES.

South Cheyenne Canyon is a miniature Yosemite with massive granite walls rising to a height of 700 or 800 feet. This view shows the road leading up to the Seven Falls and to the original grave of Helen Hunt Jackson. Here and there the rocky walls are relieved by the soft foliage of trees that grow in clefts in the rocks, and the rippling stream wanders along beneath a tangle of shrubs and creeping vines. Photograph furnished by the Cheyenne Canyon & Seven Falls Development Co.

SEVEN FALLS.

South Cheyenne Canyon ends abruptly at the Seven Falls, as shown in this view. The reason for the deep cutting up to this point is the presence of a zone of crushed rock, which is shown on the left. The stream comes in from another direction where the granite is massive and has made little headway in cutting a canyon. Eventually it will wear away the hard granite, and then the Seven Falls will become a series of cascades or rapids. Photograph furnished by the Cheyenne Canyon & Seven Falls Development Co.

miles into what is now the heart of the mountains, with isolated low ranges here and there projecting above their even surface. Then came a great uplift which finally raised the mountains to their present positions. On this uplifted mass of rock the streams, on account of their increased slope, were very active and at once began to cut deep trenches; these in time were widened where the rocks were soft, and finally all the higher land on the plains was cut away, but in the

comparatively low grade. The great number of veins and the ever-present possibility of finding a rich shoot at some hitherto overlooked junction of inconspicuous fissures has made the district a favorite field for lessees, and many prizes have been won by men working small blocks of ground leased from their owners. The great Independence mine, which made a fortune for Stratton and whose history constitutes one of the romances of mining, is now worked entirely by the leasing system.

The production of the Cripple Creek district is shown by the following table, compiled by Charles W. Henderson, of the Geological Survey:

Gold and silver produced in the Cripple Creek district, Colo., 1891–1920.

Year.	Ore (short tons).	Lode gold (value).	Silver.		Total value.
			Quantity (fine ounces).	Value.	
1891	.....	$1,930	.....	.....	$1,930
1892	.....	557,851	.....	.....	557,851
1893	.....	2,021,088	5,680	$4,430	2,025,518
1894	.....	2,618,388	25,335	15,961	2,634,349
1895	.....	6,166,144	68,428	44,478	6,210,622
1896	.....	7,413,493	63,617	43,260	7,456,753
1897	.....	10,131,855	59,879	35,927	10,167,782
1898	.....	13,507,349	67,799	40,001	13,547,350
1899	.....	16,058,564	82,299	49,379	16,107,943
1900	.....	18,149,645	80,792	50,091	18,199,736
1901	.....	17,234,294	89,560	53,736	17,288,030
1902	.....	16,932,416	62,780	33,273	16,965,689
1903	.....	11,840,272	41,605	22,467	11,862,739
1904	597,819	14,456,536	47,817	27,734	14,484,270
1905	716,358	15,641,754	56,951	34,740	15,676,494
1906	702,069	13,930,526	67,943	46,201	13,976,727
1907	451,082	10,370,284	51,630	34,076	10,404,360
1908	601,173	13,031,917	52,270	27,703	13,059,620
1909	575,670	11,466,227	63,204	32,866	11,499,093
1910	688,941	11,002,253	54,263	29,302	11,031,555
1911	756,900	10,562,653	57,783	30,625	10,593,278
1912	849,172	11,008,362	66,117	40,662	11,049,024
1913	917,406	10,905,003	71,349	43,095	10,948,098
1914	939,423	11,996,116	89,056	49,248	12,045,364
1915	948,082	13,683,494	87,767	44,498	13,727,992
1916	945,820	12,119,550	79,804	52,511	12,172,061
1917	1,084,656	10,394,847	64,568	53,204	10,448,051
1918	936,326	8,119,747	50,665	50,665	8,170,412
1919	775,986	5,827,816	35,442	39,695	5,867,511
1920	448,618	4,323,998	33,789	36,830	4,360,828
	.....	311,474,372	1,678,192	1,066,658	312,541,030

Formerly a considerable part of the ore from the district was sent directly to the smelters at Pueblo and Denver, but about 96 per cent is now treated in mills in the district, chiefly near the town of Victor or in mills near Colorado Springs. The common practice has been roasting and cyanidation, but in the modern Victor mill of the Portland Gold Mining Co. concentration is effected by flotation and the concentrates are treated by the cyanide process.

hard rocks of the mountains the streams have succeeded in cutting back only a short distance and have formed canyons like that of South Cheyenne. At some places in South Cheyenne Canyon this backward cutting has proceeded rapidly because the granite is shattered, but at the Seven Falls the joints and fissures in the rock extend to one side, as shown in Plate XXX, whereas the stream tumbles over a wall of the most massive rock imaginable, and the canyon ends so abruptly that it seems almost as if it had been the work of man. If the rock were not of this character the stream would probably have cut considerably farther back, and in that event the Seven Falls would probably have been replaced by a series of cascades. In time this cutting will doubtless be accomplished, for the stream is always at work—it knows no cessation from its labors—and, although the work of cutting the granite is extremely slow when compared with human standards, it is continuous, and if conditions remain the same as they are to-day the canyon will be cut far back into the mountain, until, in even more remote time, the mountains themselves may be worn down and a plain may be found where now we have our grandest scenery. The regularity and smoothness of the walls of South Cheyenne Canyon are due largely to the massiveness of the granite in which the canyon is carved.

The traveler should climb to the top of the falls, where he can obtain a much better idea of the magnitude of the gorge, and then he will doubtless be impelled to climb still higher, to Inspiration Point, which is said to be the spot most beloved by Helen Hunt Jackson, the place where she wrote many of her most noted works of fiction. One can hardly imagine a more inspiring sight than that of Colorado Springs and the broad stretch of plain seen from this point; and here, amid the grandeur of the mountains, the romantic imagination of so ardent a lover of nature would readily be quickened into new life. She pays this tribute to Inspiration Point:

> Beautiful cradle of peace! There are some spots on earth which seem to have a strong personality about them—a charm and a spell far beyond anything which mere material nature, however lovely, can exert; a charm which charms like the beauty of a human face; and a spell which lasts like the bond of a human relation. In such spots we can live alone without being lonely. We go away from them with the same sort of sorrow with which we part from friends, and we recall their looks with the yearning tenderness with which we look on the photographs of beloved absent faces.

Although Helen Hunt Jackson died in California, her last request was that her body be brought back and laid to rest in this spot on Cheyenne Mountain that she so dearly loved and that the place be marked only by the boulders which nature had provided. This was done, and many thousand travelers still visit the grave annually and pay tribute to the gifted author, though her body now lies in Evergreen Cemetery, Colorado Springs.

If the traveler returns from the canyon late in the afternoon he may see some of the beauty of the plains as it appeared to her poetic imagination:

> Between the pines and the firs are wonderful vistas of the radiant plain. Each glimpse is a picture in itself—now an open space of clear sunny distance; now a belt of cottonwood trees making a dark-green oasis in the yellow distance; now the majestic bluffs, looking still more castle-like, framed in the dark foreground lines of pine boughs. We are in shadow. The sun has set for us; but it is yet early afternoon on the plain and it is brilliant with sun. * * * The brilliance slowly fades, and the lower sunset light casts soft shadows on every mound and hill and hollow. The whole plain seems dimpling with shadows; each instant they deepen and move eastward; first revealing and then slowly hiding each rise and fall in the vast surface. Away in the east, sharply against the sky, lines of rocky bluffs gleam white as city walls; close at the base of the mountain the foothills seem multiplied and transfigured into countless velvet mounds. The horizon line seems to curve more and more, as if somehow the twilight were folding the world up for the night, and we were on some outside shore watching it.

MAIN LINE OF RAILROAD FROM COLORADO SPRINGS TO CANON CITY.

On leaving Colorado Springs the Denver & Rio Grande Western Railroad follows down the valley of Fountain Creek, which is irrigated and under intensive cultivation. For a number of miles Cheyenne Mountain is the most conspicuous object on the west (right), and the abruptness with which the mountain ends and the plains begin is striking. As explained before, this abrupt junction of plain and mountain is due to a great fault, which bounds the mountain

FIGURE 13.—Section showing fault at foot of Cheyenne Mountain.

on the east and brings its hard rocks into contact with the soft, flat-lying rocks of the plains. (See fig. 13.) Consequently there are no hard sandstones to form foothills, as there are about Manitou and many other places along the Front Range.

The railroad continues its southerly course down Fountain Creek, and the traveler whose destination is the Pacific coast or some intermediate point is apparently getting no nearer his destination than he was at Denver or Colorado Springs. He may have wondered why it is that the Denver & Rio Grande Western, an important link in one

of the great transcontinental railway systems, should, after starting from Denver, go due south 119 miles, to Pueblo, before attempting to cross the mountain range in a westerly direction. It is generally assumed that the road was built southward in order to reach the valley of the Arkansas and that this valley affords the best route through the mountains. This can hardly have been the reason for the southward extension, however, for other roads cross north of Pueblo and Canon City, and hence there must have been some other reason for the course pursued by this road. The explanation of this southerly course is bound up in the general railroad history of this mountainous region, a brief account of which is given in the footnote below.[18]

[18] Considerable difficulty was experienced in the early days of Colorado in getting moneyed men interested in the construction of railroads in or across the mountains, but by the persistent efforts of those who had become identified with the movement to develop the natural resources of the State capital was obtained and the building of railroads was begun.

The Denver & Rio Grande Railroad was incorporated October 27, 1870. The leading spirit in the organization and building of the road was Gen. William J. Palmer, a Philadelphian by birth, who had received his early railroad training on the Pennsylvania Railroad under the presidency of J. Edgar Thompson. He served with distinction in the Civil War and earned the rank of brigadier general in the Army of the Tennessee under Gen. George H. Thomas. Upon the conclusion of the war he became managing director of the Kansas Pacific Railroad and was placed in charge of the construction of the last division, extending from Kit Carson to Denver. Here he accomplished the almost impossible task of building 150 miles of railroad in the same number of days without having materials of any kind to begin with. It is doubtful if this record in railroad construction has ever been equaled. When this road was completed, Gen. Palmer became interested in the mountain region of Colorado and, like the true empire builder that he was, foresaw wonderful possibilities in creating a system of transportation that should cover the entire region. In speaking of him, William J. Beyers, founder and for a long time editor of the Rocky Mountain News, says:

"The Denver & Rio Grande Railroad, with its numerous branches in the mountains, was Gen. Palmer's conception. It was a comprehensive scheme, by many regarded as Utopian, because it contemplated the construction of hundreds of miles of railroad through a country practically uninhabited and generally considered unfit for habitation. Aside from a few white settlers at Pueblo, small Mexican settlements at Trinidad, a village of pioneers at Colorado City, small bands of Cheyenne and Arapahoe Indians, and scattered settlers at some other points, there were not enough inhabitants for the nucleus of a community anywhere on the proposed line. But Gen. Palmer's prevision penetrated farther than the vision of others who looked with doubt and suspicion on the enterprise. He proposed to lay tribute on the hidden treasures of the mountains and to stimulate production of the precious metals by affording facilities for shipment and to encourage the farmer and ranchman to occupy the plains for the purpose of agriculture and stock growing by affording the means of quick transportation to distant markets. It was gigantic, a daring proposition, but not visionary, for the man who conceived

Near milepost 85 the Santa Fe Railway crosses the Denver & Rio Grande Western by an overhead bridge, and a short distance farther on it crosses to the right bank of Fountain Creek.

Fountain.

Elevation 5,577 feet.
Population 595.
Denver 88 miles.

Three miles below the overhead bridge is Fountain, the largest village in the southern part of El Paso County. The lower part of Fountain Creek valley is not particularly interesting to the traveler. There is little or no irrigation, and success with dry-land crops depends

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it was able to procure the necessary capital to complete the undertaking. No single agency has done more to establish mining camps and open valuable mines in Colorado than the projection and completion of this vast and complex system of mountain railroads."

In 1870 only one road, the Union Pacific, had been built across the continent, and this road was north of Colorado, where the low passes presented no great difficulties. Gen. Palmer's scheme was not to build an east and west line but a north and south one. As stated in the first annual report of the board of directors:

"The idea of a north and south railway, following the eastern base of the Rocky Mountains from the principal city of the new West—Denver—southward to Mexico, arose from a conviction that this belt of country had especial advantages in its location, climate, and natural resources."

It was urged that a railroad in this direction would traverse a belt of country having an excellent climate and well watered by mountain streams; that it would be closely adjacent to the mountains, which contain silver, gold, lead, copper, iron, and other metals, as well as abundant supplies of timber for manufacturing and construction; that it would tap several fields of coal well suited for making steam and for general manufacturing; and lastly, that it would control the freight business in this isolated territory and would levy tribute on any east and west road that might be constructed through it.

The main line of the Denver & Rio Grande, according to Gen. Palmer's scheme, was to extend from Denver to Pueblo, thence up through the "Big Cañon" (Royal Gorge) of the Arkansas to Salida, thence southward through Poncho Pass to Alamosa on the Rio Grande, and thence down that stream to El Paso and on to Mexico City. A loop was to extend south of Pueblo through La Veta Pass and connect with the other line at Alamosa, and still another line was to be built through Raton Pass south of Trinidad. Branch lines were projected into the mountains at many points, two of which had Salt Lake City as their objective. A map of the system as originally planned is given in Plate XXXI.

Gen. Palmer was a great believer in the economy of construction and operation, in a mountainous country, of a narrow-gage road, so after careful consideration and investigation of such roads abroad, a 3-foot gage was decided upon for the new road. This did not meet with general approval, and for a long time it was referred to as the "baby railroad," a name which seems singularly appropriate when the rolling stock of that day is compared with the rolling stock of the present time. (See Pl. XXVII, *A*, p. 48.)

Track laying was begun at Fifteenth Street in Denver on July 27, 1871, and the road was completed to Colorado Springs, 75 miles away, by October 21 of the same year. Construction was pushed southward rapidly, and the road reached Pueblo June 29,

upon the amount of precipitation, which, according to the Weather Bureau, is only about 11.6 inches annually. In time of drought the valley is brown and desolate, but when showers are abundant all the plains are green and smiling. On a clear day the traveler may obtain glimpses of the distant mountains. Toward the northwest he can see Cheyenne Mountain, dominated by the towering summit of Pikes Peak, fading into the blue and hazy distance; on the west he may be able to distinguish the outline of the Wet Mountains, showing faintly in the distance; and far away to the south he may catch the faint blue of two peaks which are commonly known as the Spanish

Buttes.

Elevation 5,386 feet.
Denver 93 miles.

Eden.

Elevation 4,882 feet.
Denver 112 miles.

1872. It is interesting to note in the first report of the company that an estimate of the passenger traffic between Denver and Colorado Springs (then just organized) was 13 persons each way daily. To-day the road handles during the summer season an average of nearly 1,500 persons a day between these places, to say nothing of those who travel over the Santa Fe and the Colorado & Southern railroads.

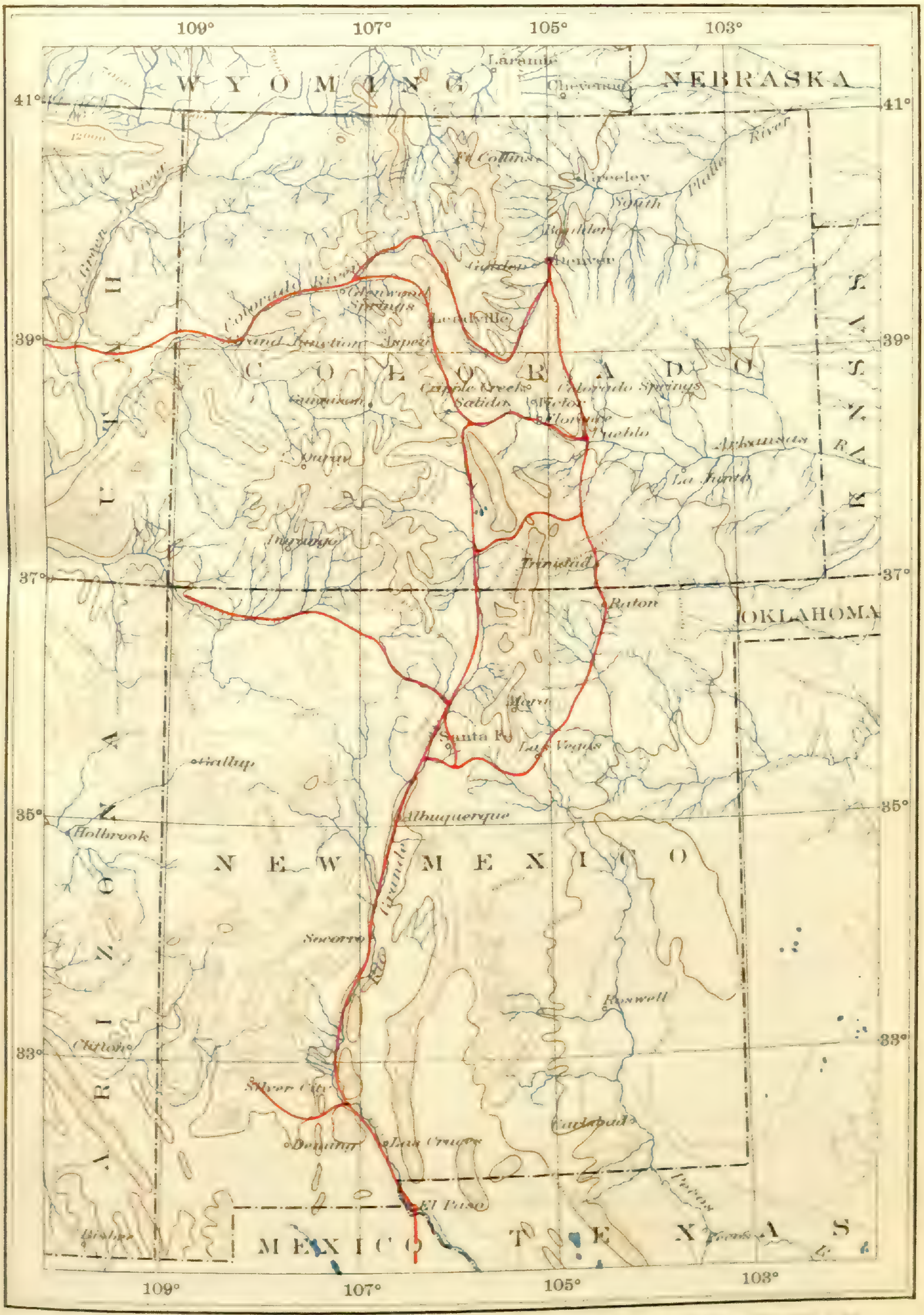
As the road needed fuel, and as it had not penetrated any field of coal suitable for use in locomotives, a branch line was built up the Arkansas Valley to the coal field near Florence in the same year (1872), and this line was extended to Canon City in 1874.

In 1872 negotiations were undertaken with the Mexican Government for the extension of the Denver & Rio Grande Railroad to Mexico City, but they were not successful, though later the plans for this extension found expression in the Mexican National Railway.

By the time the Rio Grande road reached Pueblo, the Arkansas Valley began to attract the attention of other railway companies, and many plans were conceived to build railroads, but nothing came of them, and the Rio Grande was left in supposed undisputed possession of the field. A little later the Atchison, Topeka & Santa Fe Railway, a Boston corporation with apparently unlimited capital and energy, entered this field without regard to any assumed prior rights of the Denver & Rio Grande.

In 1872 the Santa Fe was in operation as far west as Fort Dodge, Kans., and a subsidiary of that road, the Kansas & Colorado Railway Co., was incorporated to build a line up the Arkansas Valley. It was understood that the Santa Fe proposed to make Pueblo the principal commercial center of the mountain region and to build several extensions beyond Pueblo, especially to Canon City and through the Royal Gorge to the mining camps in the mountains, as well as to Denver and other places along the mountain front. It was rumored that the Santa Fe was heading for Raton Pass, south of Trinidad, which was claimed by the Rio Grande as a part of one of its southern routes. All these plans threatened seriously the very existence of the Denver & Rio Grande, which accordingly made preparations for a vigorous defensive campaign, but the panic of 1873 stopped nearly all construction work on the Rio Grande as well as on most other roads in the country.

Four or five years later, as confidence was restored and money became plentiful, work was pushed ahead on all the lines entering the Rocky Mountains. The Rio Grande resumed work on one of its branches through La Veta Pass into San Luis Park, reaching Alamosa July 6, 1878.



MAP SHOWING DENVER AND RIO GRANDE RAILROAD AS ORIGINALLY PLANNED

Scale 1/7,000,000

100 50 0 100 200 MILES

Contour interval 1,000 feet

1922

Peaks but which might more properly be known by their poetic Indian name Wahatoya (meaning twin breasts).

The first indication of an actual clash between the rival roads occurred in February, 1878, when the Santa Fe plotted to occupy Raton Pass, through which one of the surveys of the Rio Grande had been run and which was therefore practically occupied by that road. Hundreds of men and teams were suddenly rushed into the pass by the Santa Fe, which built its line through the pass before the Rio Grande could stop its progress. This sudden move created consternation in the offices of the Rio Grande, and for a time it seemed impossible to avoid armed conflict. Although much bad feeling was created by this action of the Santa Fe no actual bloodshed occurred, and that road was allowed to retain possession of the pass.

The great contest between the two systems, however, was that for the right of way through the Royal Gorge. As the Santa Fe had been successful in its sudden move in Raton Pass, it planned a similar attack on the Royal Gorge before the Rio Grande had time to defend its own property. The Rio Grande, however, had possession of the telegraph lines and so was apprised of the proposed attack. Accordingly, the Rio Grande planned as a defensive measure to begin grading in the Royal Gorge on April 20, 1878. The general manager of the Santa Fe heard of this plan and wired an engineer at La Junta to proceed to Canon City immediately and occupy the canyon before the Rio Grande forces appeared. The engineer arrived at Pueblo at 3 o'clock on the morning of the expected move. He tried to charter a train on the Rio Grande to carry him to Canon City but of course was refused; then he hired the best horse he could obtain and started at breakneck speed to ride to Canon City, 45 miles distant. He had to reach the canyon before the engineers of the Rio Grande, so he spurred his horse to top speed, but when he was within 3 miles of his destination it fell dead. The engineer ran on into Canon City, raised a force of several hundred men, proceeded to the mouth of the canyon, which is admirably suited for such a purpose (Pl. XXXIII, *B*, p. 71), and fortified his position before the Rio Grande force appeared. The ease with which the engineer of the Santa Fe raised a force of men at Canon City was due to the fact that the Rio Grande had become very unpopular through its autocratic habit of ignoring the wishes of the citizens of the region, so the people were glad to have an opportunity to assist the Santa Fe in order to "get even" with the Rio Grande.

The Santa Fe was operating through a subsidiary corporation, the Canon City & San Juan Co., which had a charter for a line in the canyon extending for 20 miles from the lower entrance. Both roads had graders at work in the canyon, and it is not surprising that fights were frequent and that many men were arrested. The Santa Fe obtained an injunction restraining the Rio Grande from continuing its work, and the Rio Grande obtained one preventing the Santa Fe from grading any more of its roadbed. About the last of May, 1878, the cases came up before Judge Hallett, of the United States court at Denver, but the judge postponed them and in the meantime enjoined both parties from working in the disputed section and placed each under a bond of $20,000.

On June 1, 1878, Federal Judges Hallett and Dillon rendered a concurrent opinion that the Santa Fe (Canon City & San Juan Co.) be permitted to resume grading in the canyon until the case could be more thoroughly examined in July. The case was ably argued in July by both sides but was again postponed. On August 23

As the train approaches the point where Fountain Creek joins Arkansas River the traveler is made aware of the presence of Pueblo

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Judge Hallett handed down a decision which granted to the Canon City & San Juan Co. (Santa Fe) the right to construct its line as surveyed—up the gorge for 20 miles. The Rio Grande was restrained from interfering in any way with this work but might proceed (if it could do so without interference) to build a parallel line, and if it became necessary might, on application to the court, be allowed to use the tracks of the rival road.

The Rio Grande appealed from this decision to the Supreme Court of the United States and began construction above the 20-mile limit of the Santa Fe, but as its financial condition was desperate and as it had been denied the right to the Royal Gorge there seemed to be no other course but to bow temporarily to the stronger road. Accordingly, on December 2, 1878, the entire Rio Grande system, embracing 337 miles of road, was leased to the Santa Fe for 30 years, the Santa Fe engaging to proceed with the work of constructing the line through the canyon to Leadville while awaiting the decision of the United States Supreme Court. Although the lease was ratified by the stockholders of the Rio Grande, it was ratified under pressure, and from the beginning it was a constant source of irritation.

As soon as the Santa Fe obtained control of the Rio Grande it proceeded to carry out its plan of concentrating business at Pueblo, and in so doing it used the Rio Grande merely as a feeder for its main line. This policy naturally aroused the opposition of the old officers of the Rio Grande, and charges of irregularities by both companies were freely made. The Rio Grande officials were trying in every way to find some valid reason for abrogating the lease, which had become to them almost intolerable.

In the spring of the next year (1879) the great struggle for the possession of the Royal Gorge was resumed. Armed parties from both sides reentered the canyon in anticipation of an early decision of the Supreme Court. In April the Rio Grande people, exasperated to the fighting point, began preparations to retake and hold, at the muzzle of the rifle if necessary, the entire system, which they claimed was being operated in violation of the principal condition of the lease. The Santa Fe learned of this contemplated action and issued strict orders to its men not to obey any instructions or orders except those of its own officers. There was trouble, however, at several places along the line; stations were broken into and considerable property was destroyed.

While the Rio Grande and the Santa Fe were waging their contest over the occupancy of the Royal Gorge, Congress passed an act which specified, among other things,

"That any railroad company whose right of way, or whose track or roadbed upon such right of way, passes through any canyon, pass, or defile shall not prevent any other railroad company from the use and occupancy of the said canyon, pass, or defile for the purpose of its road in common with the road first located."

This act was approved March 3, 1875. On May 6, 1879, the Supreme Court of the United States rendered a decision which gave to the Rio Grande the prior right to construct its road through the Royal Gorge according to the first survey made through the canyon in 1871–72, but in accordance with the law of 1875, quoted above, it recognized that the Santa Fe could not be prevented from building a line also, and where the canyon is too narrow for both roads from using the tracks of the Rio Grande. Although this decision was a victory for the Rio Grande, this road had not succeeded in having the lease annulled and was in

by the pall of smoke that overhangs this "Pittsburgh of the West," as the citizens like to have it called. Pueblo is essentially a manu-

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the anomalous position of having the first right to the canyon but being estopped from occupying the roadbed on the north side of the canyon that had been graded by the Santa Fe and of having its whole system under lease to the rival road.

While these points were being considered, the attorney general of the State entered a suit to enjoin the Santa Fe from operating a railroad in the State of Colorado. This case was heard by Judge Bowen at the obscure town of San Luis, in Costilla County. Judge Bowen enjoined the Santa Fe from operating the Rio Grande Railroad and from exercising corporate rights within the State. This decision gave the Rio Grande opportunity to regain control of its own road under judicial authority, and accordingly the sheriffs of the counties in the State were instructed to take possession of the property and turn it over to the Rio Grande officials. Wild rumors were afloat that the Rio Grande had organized fighting forces that were attacking the Santa Fe men at several points along the line. The offices of the Santa Fe at Denver were broken open and occupied by Rio Grande men. The governor was petitioned to call out the militia to stop bloodshed, but he left the matter entirely in the hands of the sheriffs of the counties.

Counsel for the Santa Fe appeared in the Federal court at Denver and moved to quash the "Bowen injunction." In the meantime the Rio Grande had retaken most of its stations, offices, and rolling stock. Great excitement prevailed, and some blood was shed. On June 12, 1879, Judge Hallett declared Judge Bowen's decision to be null and void, and on June 23 he decided that the Rio Grande had unlawfully retaken property and should immediately restore it to the Santa Fe; then, if the Rio Grande so desired, it might institute proceedings for the cancellation of the lease. He also decided that the Rio Grande might take possession of the narrow part of the Royal Gorge by paying to the Santa Fe the cost of construction. On July 14 the Federal court ordered all work stopped in the canyon pending an examination by a commission of engineers to determine the cost of construction. While these court proceedings were in progress the Rio Grande engineers erected fortifications and stopped the Santa Fe graders at the 20-mile limit specified in their charter.

On January 2, 1880, the Federal Supreme Court rendered its long-expected decision as follows:

"That from the mouth of the canyon to the mouth of the South Arkansas River [Salida] the Rio Grande was to take and hold the prior right of way; that it might take the roadbed of the Santa Fe in that part by paying for it at the rate determined by the commissioners; when paid for, all injunctions and restraining orders to be dissolved and set aside, and the Santa Fe was perpetually enjoined from interfering. From South Arkansas River to Leadville the prior rights belonged to the Santa Fe by reason of prior location."

Soon after this the long fight between the two railroads was terminated by a compromise agreement in Boston by which the Rio Grande was not to build its contemplated line to El Paso, Tex., nor its proposed line eastward to St. Louis, the Santa Fe was not to build to Leadville, the lease was to be canceled, and the Rio Grande was to pay the Santa Fe for all grading it had done in the canyon. Thus ended one of the longest and most bitterly contested railroad wars that were ever fought in this country. In the legal battles some of the most noted lawyers of the West were employed, and the encounters in the field were

facturing community and is the largest town of this kind in the Rocky Mountain region. Indeed, it is generally considered the greatest manufacturing center between Missouri River and the Pacific coast. Pueblo is in the Arkansas Valley,[18a] which is well watered and capable of supporting a large population. Already the valley is well farmed, but with the construction of storage reservoirs to hold the water in the upper courses of the river and deliver it as it is needed below for irrigation the valley would support many times its present population. Pueblo has abundant railroad connections, both for the receipt of crude material to be manufactured and for the distribution of the manufactured products. Coke can readily be obtained from the Trinidad field, on the south,

Pueblo.

Elevation 4,668 feet.
Population 43,050.
Denver 119 miles.

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marked by deeds of heroism and bloodshed that were worthy of a better cause.

Thus we see that the Denver & Rio Grande, originally planned as a north and south line, was compelled to become an east and west line, much to its ultimate advantage, and although it made a most vigorous effort to reach the Rio Grande with its main line, it failed to do so.

After the compromise construction was carried forward rapidly, and the narrow-gage line reached Leadville in July, 1880. The first line across the Continental Divide—the line over Marshall Pass—was completed to Gunnison in August, 1881. The line over Tennessee Pass—the present main line—was completed in the following year. The line from Marshall Pass was pushed westward, reaching Grand Junction in November and the Utah State line in December, 1882.

About this time the Pleasant Valley Railway of Utah, extending from Provo to Clear Creek, was purchased by Gen. Palmer and the Denver & Rio Grande Railroad and extended eastward to the Colorado line under the name Rio Grande Western Railroad. This made a through narrow-gage line from Denver to Salt Lake City, which was completed to Ogden a year later. The laying of a third rail to give standard gage between Denver and Pueblo was completed on December 23, 1881, and the main line from Denver to Ogden was changed to standard gage by the autumn of 1890.

Several of the branch lines of this system are still narrow gage, and the traveler who wishes to see Marshall Pass and the Black Canyon of the Gunnison will have ample opportunity to compare the narrow, cramped cars and small engines of the narrow gage with the modern equipment of a standard-gage line.

Recently the company has been reorganized, and the name Denver & Rio Grande Western Railroad has been adopted for the entire system.

[18a] On June 3–5, 1921, a succession of flood waves occurred in Arkansas River as a result of heavy rains of "cloud-burst" violence in the drainage basins of several small streams tributary to the Arkansas above or near the city of Pueblo. The highest flood wave and the one that caused the greatest damage reached Pueblo during the evening of June 3, when a stage 6½ feet above the tops of the levees was reached. At this time water 10 to 15 feet deep flowing through the lower parts of the city drowned many people and wrecked scores of buildings. The property losses caused by the flood in the Arkansas River valley aggregated nearly $20,000,000. The flood is described in detail in U. S. Geol. Survey Water-Supply Paper 487, The Arkansas River flood of June 3–5, 1921.

which is the greatest field of good coking coal in the West, and coal for fuel can be obtained from the same field or from the Canon City field, on the west. Iron ore is available in southern Wyoming and possibly in other parts of the mountain region, and altogether Pueblo is remarkably well located to become a large and prosperous manufacturing city.

At Minnequa, a suburb of Pueblo, on the mesa to the south, is the great plant of the Colorado Fuel & Iron Co. There also are smelters for the reduction of the gold and silver ores of the mountain region, as well as other manufacturing plants. Pueblo is the county seat of Pueblo County. Here is the State Asylum for the Insane, a "palace" for the display of the mineral resources of the county, and numerous business blocks, hotels, and amusement parks.

Pueblo is one of the historic places of Colorado. The first record of occupation of this region by the white man is that of the exploring party of Lieut. Zebulon M. Pike, which camped at "The Forks," as he called the confluence of Fountain Creek and Arkansas River, in November, 1806, and built a log breastwork for defense. The party made this camp before they attempted to scale the great peak which they saw far off and which is now known as Pikes Peak. The next American party to visit the site of Pueblo was that of Maj. Long, in 1820. After this time it was visited by many explorers and hunters, and James Beckwourth—a mulatto who had lived among the Indians—claimed the honor of establishing in 1842 the first permanent settlement where Pueblo now stands. Here was built an adobe fort, called Fort Napeste, which is said to have been the Indian name for Arkansas River. In 1859 a settlement was begun on the east side of Fountain Creek, which was called Fountain City. A year or two later a rival town was laid out on the banks of the Arkansas and named Pueblo. For a number of years the growth of these pioneer settlements was slow, and it was not until the Denver & Rio Grande Railroad reached the Arkansas in 1872 that the settlements consolidated and began their phenomenal growth.

On leaving the station at Pueblo the train begins its real westward journey. From Denver to Pueblo its course has been nearly due south along the mountain front, but when it turns west at Pueblo it must travel 41 miles before it again comes to the foot of the mountains, for the range that forms the mountain front from the north line of the State to Colorado Springs terminates in Cheyenne Mountain, a few miles south of Colorado Springs, and here the mountain front is offset to the west 25 or 30 miles, to a point west of Canon City. This southern range, which is the Wet Mountains, continues southward for some distance and dies out, and still farther south there is another westward offset, the Sangre de Cristo Range, which extends as far as Santa Fe, N. Mex.

The course of the railroad from Pueblo is directly up Arkansas River to its headwaters at Tennessee Pass, near Leadville. East of Canon City the river has cut for itself in the plain a valley which ranges from half a mile to a mile in width and from 50 to 150 feet in depth. As the railroad is generally only a few feet above water level the traveler has few opportunities of seeing the country through which he is passing, except at places where the hills recede or their height is less than usual. The principal views that he gets will be those of the valley bottom and of the cliffs that bound it on either side.

The region through which the train is now passing, as well as that which it has traversed since it left Denver, was once included in the fanciful Territory of Jefferson,[19] which was fully organized and carried on for a number of years but which failed to be sanctioned by

[19] Few persons of the present generation are aware that a Territory, called the Territory of Jefferson, was organized in the mountain region of Colorado and Wyoming at the time of the great "rush" to the Pikes Peak region, and that not only was the Territory organized but a serious attempt was made to organize a State without the preliminary steps of passing through a Territorial form of government. Such a statement now reads like fiction; but when this attempt was made the people were in deadly earnest and imagined that by taking vigorous action they could compel Congress to recognize and legalize their action.

When the Territory of Kansas was organized, in 1855, it included all of what is now known as Colorado that lies east of the crest of the Rocky Mountains. Thus the site of the city of Denver as well as all of eastern Colorado was within the jurisdiction of the Territorial government of Kansas. The control by that government was merely nominal, and as its seat was far off and difficult to reach the people of the mountain district were inclined to pay little attention to its authority.

When gold was reported in the Pikes Peak region, late in 1858, the few pioneers here became imbued with the idea that this was the richest part of the continent and that when its wonderful stores of the precious metal became known people would flock here in numbers so great that some sort of government other than that afforded by far-off Kansas would be necessary for the protection of life and property. These pioneers, although they were but recent arrivals, did not believe in waiting for action by the Territory of Kansas or by Congress; they proceeded to organize a government which they hoped Congress might approve and legalize. In the autumn of 1858 a few men from the settlements about Cherry Creek (the site of Denver) assembled for the purpose of creating a new State or Territory in the Pikes Peak region. This new political division was to be considerably larger than the present State of Colorado, as shown by the accompanying sketch map (fig. 14), and was to be called Jefferson, in honor of the President of the United States, who had been instrumental in executing the Louisiana Purchase, which included most of this region. This convention met in Denver City in April, 1859, and passed a series of resolutions preparatory to the organization of the State of Jefferson, hoping by this action to start it full-fledged upon its career of statehood. The convention also issued a

the United States Congress and consequently never had any legal status. The episode is interesting as giving an early indication of that "push" which is generally regarded as characteristic of the people of Colorado.

call for a general election on May 9 of delegates to a State convention to organize the State of Jefferson.

The delegates met in Denver City June 6, 1859, and appointed committees to frame a State constitution and to report at an adjourned meeting on August 1. Before the time for this adjourned meeting the people began to realize the great expense of a State government, and many decided to favor a Territorial form. The result of this difference of preference was a compromise resolution to submit both propositions to the voters. The election was held on September 5 and resulted in the decisive defeat of the proposal for statehood and in favor of a Territorial form of government.

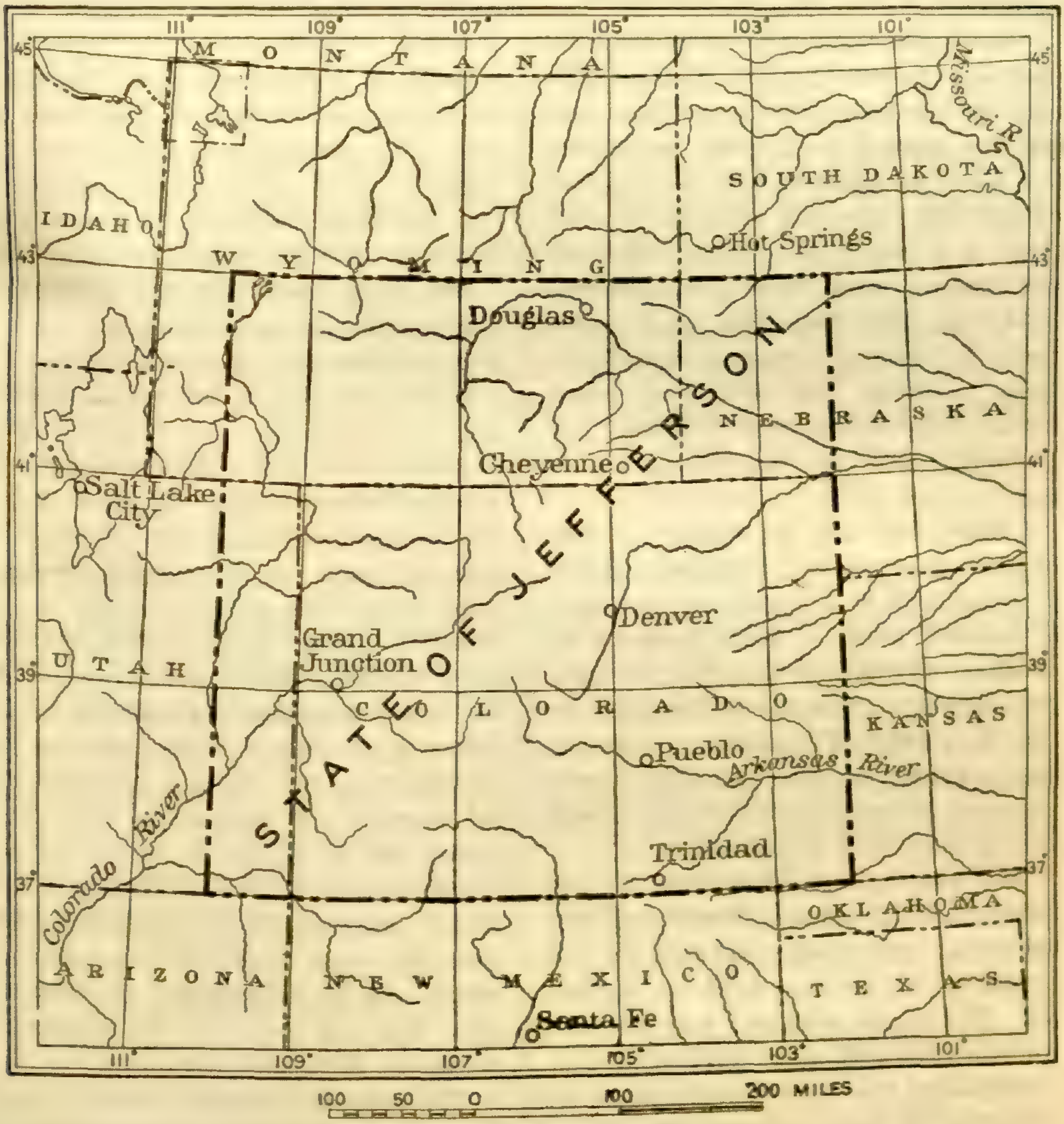

FIGURE 14.—State of Jefferson, as proposed in 1858.

On October 3, 1859, a call was sent out for an election of delegates to a convention to organize the Territory of Jefferson. Many of the participants in this movement fully realized its illegality, so in order to be on the safe side they prepared a county ticket, to be voted on at the same time, providing for the election of officers of

In the disturbance of the earth's crust that produced the mountains the rocks of the plains were thrown into low, broad folds or were sharply broken where the stresses were most severe. Folds of this kind may be seen by the traveler between Pueblo and Canon City, but they are so slight that he can hardly recognize them with-

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Arapahoe County, Kans., and also of a delegate to the Kansas Territorial legislature. An editorial in the Rocky Mountain News of October 6, 1859, says:

"So it goes; one day we understand that we are cut off from Kansas; the next we have cut ourselves off and will pay no regard to Kansas legislation but have an independent government of our own; and the very next, when there is a chance for a petty office under Kansas laws, there are hundreds ready to enter the lists, and before their certificates of election are dry in their pockets you will hear them lustily advocating 'independent government' and 'let Kansas go to the dogs.'

"Here we go, a regular triple-headed government machine. South of [parallel] 40 we hang on the skirts of Kansas; north of 40 on those of Nebraska. Straddling the line, we have just elected a Delegate to Congress for the Territory of Jefferson; and ere long we shall have in full blast a provisional government of Rocky Mountain growth and manufacture."

The convention assembled on October 10 and formed a Territorial constitution, which was ratified by the people at an election held on October 24. The name Jefferson was retained for the proposed new Territory.

Although the leaders recognized the illegality of their actions, Territorial officers and a legislature, the "First General Assembly," were elected. The legislature began its first session in Denver City November 7, 1859. The Rocky Mountain News was an ardent supporter of the Jefferson Territorial government and in its issue published after the meeting of the legislature made the following glowing prediction of the future of the Territory;

"We hope and expect to see it stand until we can boast of a million people and look upon a city of a hundred thousand souls having all the comforts and luxuries of the most favored. Then we will hear the whistle of locomotives and the rattle of trains arriving and departing on their way from the Atlantic and Pacific. * * * The future of Jefferson Territory, soon to be a sovereign State, is glorious with promise."

The first session of the legislature was marked by the enactment of many general laws and special acts, and the members seemed to have been imbued with the idea that they were building a great mountain commonwealth, but in the following year interest in the Territorial government of Jefferson began to wane, as the people realized that their efforts were likely to be fruitless. Not entirely disheartened, Gov. Steele issued a proclamation for the annual election of officers in the autumn of 1860, as provided in the constitution, but in this proclamation he warned all candidates that they would be expected to serve without compensation. This warning was given because of the growing belief that the local Territorial government would not be recognized by Congress and that all acts of its legislature would be declared invalid.

The second general assembly convened in Denver City on November 12, 1860, but on account of opposition by the city to the continuation of the legislative farce, it adjourned on November 27 to Golden. The principal inducement for this action, according to the News, was that "board is offered at $6 a week—wood and lights and hall rent free." The members, however, lost interest in its proceedings, and after 40 days playing at

out following closely the rocks outcropping in the cliffs. Thus, a short distance west of the station at Pueblo the traveler may notice on the south (left) that the cliffs are composed of a dark shale, which is the bottom bed of the Pierre shale, of Cretaceous age. A little farther along a chalky rock rises from below the river, and the dark shale can be seen only in the upper part of the cliff, and within a short distance it disappears altogether. The chalky rock is the Niobrara, which in many places consists largely of limestone but here consists mostly of calcareous shale and thin beds of limestone having a total thickness of 600 or 700 feet. Farther west the Niobrara also rises to the tops of the cliffs, and near milepost 122, it gives place to the Carlile shale, which is about 210 feet thick. Half a mile farther on this shale is replaced by a bed of massive limestone (Greenhorn), which like the others rises gradually westward in a great fold, described below. Below the Greenhorn limestone lies the Graneros shale, which in its upper part contains considerable sandstone in thin layers. This formation is 200 feet thick.

The fold in these beds, which is here cut directly through by Arkansas River, has lifted them into a broad, flat dome. The center of this dome is marked by a thick bed of sandstone (Dakota), which is just brought to the surface near milepost 126 but which the river has not yet succeeded in cutting through. The rocks dip slightly in all directions from this central part. If the traveler has been following the formations from Pueblo he has seen at least 1,200 feet of rocks rise from below river level. Originally these rocks may have formed a large hill at this place, but the river has kept them washed away possibly as fast as they rose, and to-day, except for the dip of the rocks, there is no evidence on the surface of such a dome.

From the center of the dome near milepost 126 the beds dip up the river in the direction in which the train is moving, and they disappear beneath the river in reverse order from that in which they appeared on the east. At Livesey siding the Greenhorn limestone has reached water level. It soon disappears, and then the beds lie nearly flat for a long distance.

All the rocks thus far exposed along Arkansas River except the Dakota contain marine shells, which indicate that they were laid

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lawmaking the last Jefferson legislature passed away. According to a statement in Smiley's History of Denver,

"Jefferson Territory made its last gasp in June, 1861. On the sixth day of that month Gov. Steele issued from Denver a proclamation announcing the arrival of Gov. Gilpin and the institution of the Government of the Territory of Colorado under the act of Congress signed by President Buchanan February 28, 1861. * * * Thus ended the most interesting and picturesque endeavor of an isolated community to establish and maintain within itself a government of and by law that the student of self-government will find in the history of this country."

down in the sea, and as these rocks are widely distributed through the United States and Canada the sea must have covered most of the continent, or at least a wide area extending from north to south. It certainly extended eastward into Iowa and westward as far as the Wasatch Mountains. The Rocky Mountains were not then in existence, for this region was occupied by a shallow sea in which animal life swarmed, much as it does in the warm, shallow seas of to-day, and many of these forms were covered with mud and almost perfectly preserved.

About three-quarters of a mile beyond milepost 132 Turkey Creek enters the valley from the north (right). Up this creek there are extensive sandstone quarries from which much stone has been taken for constructing buildings at Pueblo. The quarries are connected with Pueblo by a branch railroad. At Swallows the Denver & Rio Grande Western crosses to the north side of Arkansas River and about a mile farther on it passes under the Santa Fe, which a short distance beyond crosses to the south side of the stream.

Swallows.

Elevation 4,887 feet.
Denver 135 miles.

West of milepost 142 the railroad crosses Beaver Creek, a large stream that joins the Arkansas from the north, and a little farther on is the station of Beaver. A short distance to the northwest is Beaver Park, which is noted for its apples, cherries, and small fruits. The land is irrigated from Beaver Creek, which derives its supply of water from the mountains on the north. At Beaver most of the formations already described or mentioned have disappeared, and the Pierre shale lies at the surface. The Niobrara formation rises again farther west, and at the towns of Cement and Portland it is used extensively in the manufacture of Portland cement.[20] The first cement mill to be seen is that of the United States Portland Cement Co. on the north (right) of the railroad, and a mile farther on, at Portland, the Colorado Portland Cement Co. has an extensive plant on the south side of the track.

Beaver.

Elevation 4,996 feet.
Denver 143 miles.

Portland.

Elevation 5,051 feet.
Population 473.
Denver 146 miles.

A short distance beyond milepost 147 the Denver & Rio Grande Western crosses the Arkansas and remains on its south side for 8 miles. West of Portland the rocks dip gently toward the west,

[20] Portland cement is an artificial product consisting of 60 to 65 per cent of lime, 20 to 25 per cent of silica, and 5 to 12 per cent of oxide of iron and alumina, and it has the useful property of hardening or "setting" under water. It is obvious that Portland cement may be manufactured from a variety of raw materials, provided the mixture has the chemical composition noted above. The most successful plants, however, are those which obtain all the necessary raw materials from the same quarry. Thus, limestone is needed for the lime and a sandy shale for the silica, iron, and alumina, but com-

the formations seen in the dome below Swallows are all below water level, and the surface of the country is composed of the Pierre shale. This shale is soft and does not form steep cliffs, and consequently the traveler here may see more of the surrounding region than he could farther east. Soon after passing milepost 147 he may see far on the right, if the atmosphere is clear, the summit of Pikes Peak, towering high above the surrounding plateau. The peak is frequently obscured by clouds which gather about its summit and stream off to the east in long banners of misty white. In the sunshine of a clear day it shows yellow or rosy red, but when the evening shadows fall or the mountain is partly obscured in the distance it is blue and hazy. The mountain is more than 30 miles from this point.

As the harder rocks disappear from view and the softer Pierre shale takes its place, the surface of the country becomes more nearly level and the hills less prominent. In this shale oil was discovered before Colorado was admitted to statehood. Florence is the natural center of the oil field, which was developed by sinking a great many wells and to-day produces more oil than any other oil field in the State.[21]

Florence.

Elevation 5,199 feet.
Population 2,629.
Denver 152 miles.

Refineries at Florence convert the crude oil into many marketable products. As the train approaches the town oil-well derricks and oil

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monly an impure limestone may furnish all the materials, or, in other words, it may be a natural cement.

At Portland and Cement two beds of limestone in the Niobrara formation are used. One of these beds is fairly pure and carries about 88 per cent of carbonate of lime; the other is less pure and contains about 71 per cent of carbonate of lime. The essential process in the manufacture of cement is the formation under intense heat of a material that has the proper chemical composition. First, the raw materials must be ground to a fine powder, dried, and intimately mixed; second, the mixture thus prepared must be burned at a high temperature until it unites chemically and physically into a clinkered mass; and third, the clinker must be ground very fine. The fine mixture of the raw materials is burned in large steel cylinders that are slightly tilted and rotated by machinery. The fuel generally used is powdered coal, which is forced into the cylinder at its lower end. The mixture is fed into the cylinder at its upper end and in the intense heat of the burning coal is fused into a clinker, which falls out at the lower end of the cylinder. This clinker when ground very fine forms the Portland cement of commerce.

[21] Oil was first discovered in the Florence field in 1872, when an oil spring was found on what is now known as Oil Creek, a stream that enters Arkansas River a few miles east of Canon City. A small still was put in operation that year, and the oil that flowed from the gravel in the stream bank was distilled for local use. It is said that this spring is still flowing at the rate of about 20 gallons a day.

The first deep well was drilled in the field in 1876 and struck oil at a depth of 1,187 feet. From this beginning the field was developed in and around the town of Florence. It extends southward for about 4 miles and westward

tanks may be seen on both sides of the railroad. From Florence a branch railroad turns to the south (left) and runs through the heart of the oil field and to Coal Creek, where there are coal mines that ship their product both east and west over the Denver & Rio Grande Western Railroad.

During the early days of mining in the Cripple Creek gold district the entire output of ore was refined at Florence. Nine enormous reduction mills were operated in this vicinity until the Golden Cycle mill was built in Colorado City, when trouble with labor caused the ore to be sent to Colorado City and Denver. The mills continued to operate for a number of years but were finally closed. One of these—a million dollar plant—is still standing on the north side of Arkansas River about half a mile north of Florence.

About three-quarters of a mile west of the station the railroad crosses Oak Creek, and from this crossing the traveler may see off to the southwest (left) the distant slopes of the Wet Mountains and nearer, but still 3 or 4 miles distant, the white-banded hills that mark the outer rim of the Canon City coal field,[22] a basin of Laramie

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for about 3 miles. The quantity of oil produced in this field in 1918 was 134,895 barrels, and the total quantity produced since the field was developed has been more than 10.500,000 barrels. The oil has a paraffin base and is a light oil, yielding a large percentage of gasoline.

The Florence oil field is apparently different from any other field in this country, as the oil is found part way down on the east side of a large structural basin or syncline. The oil does not come from sands, as the drillers call any coarse-grained rock that carries oil, but from the fine Pierre shale. It does not, however, appear to be in the pores of the shale but in cracks and crevices. In drilling wells in this field the tools often drop several feet, and sometimes the bailer—a long tube by which the oil or water is bailed out of the well—has been lost in one of these crevices. Altogether, this field is an anomaly and is not well understood by geologists.

Another curious fact is that the oil which flows from the spring noted above, as well as from others that have been discovered more recently, does not come from the outcrop of this shale but from the Morrison formation, which underlies the shale and is beneath the Dakota sandstone.

The Florence oil field is the largest field of its kind in Colorado and has been a steady producer for a long time. Two refineries are in operation, and the oil is piped to the railroad from different parts of the field as well as shipped in from other fields in the State for refining.

[22] The Canon City coal field is a small structural basin, or syncline, in the Laramie formation south of the Denver & Rio Grande Western Railroad and extends from a point a short distance west of Florence to the foot of the Wet Mountains. The coal-bearing beds on the east side of this basin dip westward at angles of 2° to 5° except at the northern margin, where the dip ranges from 5° to 15°. Their outcrop here, which is broader than it is on the west side, is 2 to 4 miles wide and about 12 miles long. It contains all the large mines of the field, eight in number, that ship their prod-

rocks which lies almost entirely south of the railroad and which furnishes fuel for many of the industries of Colorado. At a point 1¼ miles beyond the station at Florence the Canon City branch of the Santa Fe Railway crosses the Denver & Rio Grande Western Railroad by an overhead bridge. This branch, which is one of the principal outlets for the coal of the Canon City field, runs to Rockvale, one of the large mining centers. Just beyond the bridge the Chandler branch of the Denver & Rio Grande Western Railroad turns to the left and enters the same field, for both roads depend upon this coal for use in their locomotives, and they also distribute much of it throughout the country for domestic and manufacturing uses.

Near milepost 154 two prominent cliffs may be seen across the river. The lower 110 feet of these cliffs consists of dark-green shale (the upper part of the Pierre shale), and this is capped by about 40 feet of massive sandstone. This sandstone may be the lowermost member of the Laramie or it may represent the Fox Hills sandstone of the north. Which sandstone it is has not been definitely settled.

Nearly half a mile beyond milepost 154 is Brewster, a signal tower at the point where the Santa Fe crosses the Denver & Rio Grande Western to the left and continues to Canon City on the south side of the river. On the south (left) is the dump of an abandoned mine on a coal bed directly overlying the sandstone described above. Old prospect entries on the same bed show on the north (right) a little farther on, and a quarter of a mile beyond milepost 155 the Denver & Rio Grande Western crosses Arkansas River and remains on the north side to a point beyond Canon City.

Just before reaching milepost 156 the railroad makes a cut through a cliff of sandstone that projects from the right. This sandstone, which dips about 10° S., as shown in the accompanying diagram (fig. 15), is the lowest sandstone of the coal-bearing rocks and forms

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uct by rail. The west side of the basin is formed by a narrow belt of nearly vertical or overturned rocks less than a quarter of a mile wide. The coal beds that are worked range in thickness from 2 to 6 feet. The coal is a high-grade domestic fuel, bituminous and noncoking. The moisture in the coal as it comes from the mines ranges from 9 to 15 per cent. and the heat value ranges from 10,500 to 12,000 British thermal units.

Mining was begun in this field in 1872 to supply fuel for the locomotives of the Denver & Rio Grande Railroad. The production of the field grew steadily, and in the last four years it has averaged about 850,000 tons a year. The total quantity of coal mined to the end of 1920 was about 23,300,000 short tons. It is estimated that the quantity of coal still remaining in the field in beds 14 inches or more thick is 992,000,000 short tons.

a part of the northern rim of the basin. The younger rocks near the middle of the coal field terminate to the south in the high ridge or escarpment of light-colored sandstone, which is a conspicuous feature of this field.

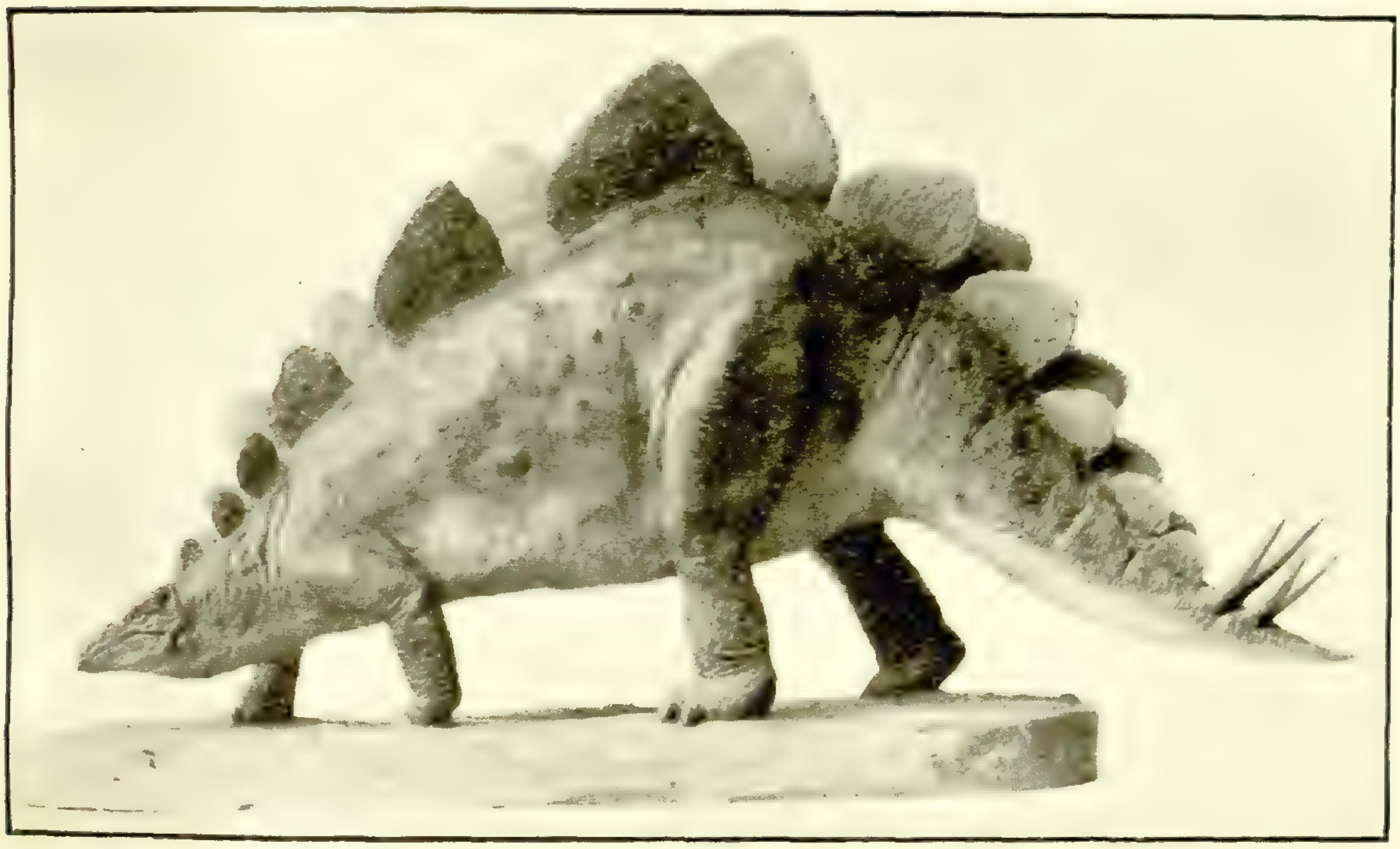
After passing the point of sandstone described above the railway runs through a broad valley, which has been cut in the same shale as that seen at Florence. This shale (Pierre) and the soft underlying formations extend to Canon City, and to them is due the breadth of the valley at and below that town. Here in the valley, where an ample supply of water can be had from Arkansas River and its tributary streams and where the crops are protected from frost by the mountains on the west, fruits—particularly apples—are grown in abundance. It is said that 50 per cent of the State's apple crop is raised in the vicinity of Canon City. Near milepost 157 apple orchards can be seen from the train, and they continue in almost unbroken masses to Canon City.

FIGURE 15. Sandstone bed at base of coal-bearing formation at crossing of Arkansas River near mouth of Oil Creek. Sandstone dips southward.

Oil Creek, so named because oil once seeped from the ground along its course in Garden Park north of the railroad, is crossed a short distance west of milepost 157.

About 8 miles up Oil Creek, in an open space at the foot of the mountains known as Garden Park, the bones of some of the most wonderful animals that the world has ever known have been found. They were embedded in the Morrison formation, and a large quarry was opened for the sole purpose of obtaining them. The skeletons or the casts of the skeletons are exhibited in most of the museums of this country. The most abundant remains are those of giant reptiles called dinosaurs. Many of these animals were 20 feet long and resembled no animal now living except possibly the diminutive so-called horned toad of California. Plate XXXII, *A*, represents one of these lizards. called *Stegosaurus*, as he is supposed to have appeared when he was alive and roamed through the swamps that then covered much of this region. This particular species was a vegetable feeder, but he needed protection from other dinosaurs that were carnivorous, so he was compelled to grow a bony plate of armor.

Dinosaurs inhabited the earth during Cretaceous time and continued to thrive on into Tertiary time, but they finally and suddenly disappeared. The last survivor appears to have been *Triceratops*, shown in Plate XXXII, *B*, a skeleton of which was found years ago in the vicinity of Denver.



A. AN ARMORED DINOSAUR (STEGOSAURUS).

Stegosaurus (plated lizard) lived long, long before man existed on the globe. His bones were found in the Morrison formation in Garden Park, 6 miles north of Canon City. The animal was 20 feet long, 10 feet high at the hips, and protected from the onslaughts of other equally powerful but carnivorous lizards by great bony plates along the back. His food consisted of the vegetation that grew on the low marshy land of that time.

B. TRICERATOPS, THE LAST OF THE DINOSAURS.

Triceratops (three-horned face) was the last of the great dinosaurs. Bones of this animal have been found in the vicinity of Denver. A mounted skeleton in the National Museum, Washington, is 20 feet long and 8 feet high at the hips. The most peculiar thing about this animal is the great bony "frill" covering and protecting his neck. From painting by C. R. Knight, made under the direction of J. B. Hatcher.

A. DINOSAUR TRACKS.

The huge dinosaurs shown in Plate XXXII sunk deeply into the sand as they fed on the rank vegetation or hunted their prey along the sandy beaches of the lakes. The sand has been hardened into rock, and to-day the three-toed tracks show almost as perfectly as they did on the day they were made. Photograph by H. E. Gregory.

B. PORTAL OF THE ROYAL GORGE.

The great cliff that forms the east portal of the Royal Gorge seems to bid defiance to those who might wish to explore the canyon above, but once this rugged gateway is passed the traveler finds that for several miles the canyon walls are not precipitous but recede gently, as shown on the left. Photograph by N. H. Darton.

Footprints of dinosaurs have been found also in sandstone that was then the sandy shore of some lake or estuary. Plate XXXIII, *A*, shows some of these tracks that were recently found in Arizona. Similar tracks were found years ago in the brown sandstone of the Connecticut Valley, and specimens may be seen in most museums. At first these three-toed tracks were thought to have been made by birds, but when the skeletons of the dinosaurs were found it was realized that the supposed bird tracks were made by reptiles.

After crossing Oil Creek the traveler may obtain on the left a general view of the mountain front back of Canon City—the mountains through which the Arkansas has cut its wonderful canyon, the Royal Gorge. In this view the gorge itself can not be readily distinguished, for it is so narrow and winding that from no point of view can it be seen as an open cut. The low gap that is most prominent from this point is the canyon of Grape Creek, which enters the Arkansas from the south (left) just above Canon City. After passing through several miles of apple orchards the train arrives at the station of Canon City.

Canon City.
Elevation 5,344 feet.
Population 4,551.
Denver 160 miles.

Canon City is rightly named, for it stands at the mouth of the greatest canyon penetrated by any railroad. It is the seat of Fremont County, which was named in honor of the "Pathfinder," Gen. John C. Frémont, who in returning from his second expedition in 1842 followed the Arkansas downstream from its headwaters until he emerged from the mountains at the place where Canon City now stands. The first recorded exploration of the canyon was that of Lieut. Pike, who camped with his little party near its eastern portal on December 5, 1806. They built a blockhouse of logs on the north side of the river, wandered about in the mountains to the north nearly a month, and on their return to their blockhouse nearly lost their lives in the Royal Gorge. The next visit of which there is a record was that of Dr. James and Capt. Bell, of the Long exploration party. On July 18, 1820, these men left their camp at the mouth of Fountain Creek (Pueblo) and rode up the Arkansas to the foot of the mountains. The seven mineral springs near the mouth of the Royal Gorge were named Bell's Springs in honor of Capt. Bell, who discovered them on that trip. After this visit the canyon was probably seen by many hunters and trappers, for several trading posts were maintained on the river. During the "rush" of gold seekers in 1859 and 1860 a town sprang up near the mouth of the great canyon and was named Canon City. Like most of the towns of that time Canon City had a varied experience and was at times nearly deserted. By 1868 it had achieved some prominence, and the Territorial penitentiary was located here. The dis-

covery of petroleum in the county in 1872 helped the new town very much, for thousands of gallons were collected and sold to the people of other settlements. Since then its growth has been steady, for the climate is agreeable, the region is well adapted to fruit raising, and the town affords an outlet for the coal mines to the south. The scenic features have heretofore been only slightly exploited but will doubtless attract many visitors.

The description of the scenery along the railroad west of Canon City begins on page 73.

ONE-DAY TRIP FROM CANON CITY TO THE TOP OF THE ROYAL GORGE.

The chief attraction in the vicinity of Canon City is the Royal Gorge of the Arkansas. The traveler passing over the Denver & Rio Grande Western Railroad in an open-top observation car has an exceptional opportunity to see this gorge from the bottom, but wonderful as this view may be, it does not compare in awe-inspiring grandeur with the view of the gorge from above. To obtain this view the traveler goes by automobile from Canon City a distance of 10 miles over one of the most picturesque drives in the country. Several years ago a trolley line was graded nearly to the top, but the enterprise fell through and at present automobiles or teams form the only mode of conveyance.

The road first climbs to the top of a steep hogback ridge formed of the sharply tilted Dakota sandstone and then follows the crest of this ridge for several miles. The top of the ridge is so narrow that there is barely room for the road; in fact, the road in many places passes beneath great projecting ledges of the sandstone. (See Pl. XXXV.) From this elevated position one can look down on the town and on acres upon acres of orchards to the east and in the other direction into the valley that separates the hogback from the main mountain. The road finally crosses this valley, climbs gradually to a high plateau, about 1,200 feet above the town, and suddenly comes to the very brink of the Royal Gorge, as shown in Plate XXXIV, *A*. When the traveler finally stands on the edge of this mighty chasm (Pl. XXXIV, *B*) and gazes down more than a thousand feet to the raging torrent that rushes through its shadowy depths or to the thundering train that wakes the sleeping echoes from all its cavernous recesses he can but feel that, though the Royal Gorge may not be so deep nor display so great a variety of colors as the Grand Canyon of the Colorado, it has a massiveness of wall and a steepness and ruggedness that can not be matched even by that "Titan of chasms." The canyon gives one the impression that Arkansas River has here acted like a gigantic saw and that what

A. TOP OF THE ROYAL GORGE.

After traversing the Skyline Drive the traveler may turn to the west and climb to the summit of the mountain in which the Royal Gorge is cut. He may be surprised to find that this mountain is really a plateau and that the automobile may be driven to the very edge of the gorge. Photograph furnished by the Denver & Rio Grande Western Railroad.

B. RIM OF THE ROYAL GORGE.

Who can describe the awful grandeur of the chasm that yawns before the traveler when he reaches the rim of the canyon? The walls are nearly sheer for a depth of 1,100 feet, and the chasm seems so narrow that he almost believes that he could cast a stone across it. The character of the rocky walls is well shown in this picture. Photograph furnished by the Denver & Rio Grande Western Railroad.

SKYLINE DRIVE, CANON CITY.

The famous Skyline Drive follows for several miles the crest of the hogback formed by the Dakota sandstone, which is so narrow that there is barely room for the roadway, and in places the heavy ledges of sandstone project over the passing automobiles. This driveway affords a magnificent view of the orchards and farms about Canon City and the mountains in the distance. Photograph furnished by the Denver & Rio Grande Western Railroad.

one sees to-day is the deep, narrow cut it has thus made. The canyon seems no wider than the stream that carved it. In places the walls overhang, and one must have steady nerves to stand firmly on the edge and look without dizziness down at a point 1,100 feet below.

The banding of the granite and the many dikes and veins that cut it, as shown in Plate XXXIV, *B*, give a variety of attractive color effects. In places the soft layers have worn away until there are deep recesses; in others the massive rock has so well resisted the scouring action of the stream that the walls are vertical or even overhang.

On the whole, the canyon shows impressively what an active stream can do when it is working on highly contorted rocks like gneiss and cutting downward only, with little or no broadening.

The view from the top of the Royal Gorge will well repay one who is interested in the canyon as a scenic feature for the trouble he takes to reach it, and it furnishes the student of geology or physiography an almost ideal example of a newly cut gorge.[23]

MAIN LINE OF RAILROAD FROM CANON CITY TO SALIDA.

As the train leaves the station at Canon City the traveler in the open-top car is prepared to see and enjoy to the utmost the magnificent spectacle of the Royal Gorge. This gorge, however, forms only a small part, as measured in miles, of the grand canyon of the Arkansas, which stretches from a point a mile west of Canon City

[23] The Royal Gorge presents to the geologist several interesting aspects that have a bearing on its history or mode of origin and also on the history of other features in this region. The canyon, as has already been stated, was carved in the rocks by the river that occupies it, but not all rivers, even in mountain regions, have carved so deeply, so some special condition here must have made it capable of producing so immense a gorge. The condition was either an uplift of the land or an increase in the volume of the river, which greatly increased its cutting power, but as there are other evidences of uplift it is safe to assume that the cutting of the Royal Gorge was made possible by a general uplift of the region. A stream that is being uplifted, or rejuvenated, as the geologist would say, begins cutting in its lower course, and the cutting progresses headward, but no matter how the cutting took place, the important fact is that the stream cuts its way slowly but surely into the surface of the land, and thus the bends and meanders that characterized the stream when it was flowing on top of what is now the plateau are perpetuated in the canyon. Cutting has not ceased in this interesting canyon but is still going on. The stream still carries sand and in times of flood great boulders, which scratch and grind the rocks over which it flows. To-day it is able to remove all these fragments of rock and its channel is being deepened, but when its grade becomes so flat that it is unable to carry the sand the cutting will cease and the stream may even fill its bed instead of cutting it deeper.

westward to a point about 3 miles beyond the small village of Cotopaxi, a distance of 34 miles.

On leaving the station the traveler sees on the south (left) the station which marks the end of this branch of the Santa Fe Railway. He is now at the place where the great railroad war was waged from 1876 to 1879, and after seeing the canyon he will understand fully that it is hardly possible for two roads to occupy this narrow gash in the rocks, and consequently each road made its supreme endeavor to be first to build through the canyon. In the 40 years that this road has been in operation thousands of travelers from all parts of the world have passed through the gorge and have admired its awful grandeur.

About a mile from the station the traveler may see on the north (right) the State penitentiary with its well-kept grounds, at the extreme farthest point of which is Iron Spring, one of the attractive features of Canon City. The pavilion that covers the spring may be seen on the right, and just opposite is the power plant, which at times fills the beautiful clear air with a dense pall of smoke. This dense cloud of black smoke should not be permitted, for when the wind is from the east it drifts up the track and conceals much of the beauty of the Royal Gorge. The rocky ledge that is exposed a few feet beyond the spring is the Dakota sandstone, which marks the base of the Upper Cretaceous series. This sandstone is the most resistant bed in the series of rocks here upturned, and it therefore stands up as a sharp-crested ridge or hogback, which extends for a long distance across the valley parallel with the mountain front. About 2 miles south of the river there is a great break (fault) in the beds of rock, separating those of the mountains from those of the plains, and the Dakota hogback ends against this fault. Along the summit of the hogback, which in places is wide enough only for a road, the famous Skyline Drive (shown in Pl. XXXV) has been constructed.

From the Dakota sandstone to the mountain front the beds are all steeply upturned, but their position can not be made out very well from the train. These beds of sandstone and limestone once doubtless extended at least as far west as Parkdale, and when the mountain was uplifted they were bowed up in a great curve, as suggested in figure 16 (p. 80), but the streams cut into these uplifted rocks very actively and in course of time removed them and even cut down hundreds of feet into the massive granite on which they rest. The first formation below the Dakota is the Morrison, which forms the west side of the hogback. It consists of variegated shale and sandstone, in which green and red beds predominate. It is in this formation that the bones of the giant reptile described on page 70 and shown in Plate XXXII, *A*, were found.

West of the outcrop of the Morrison lies a red sandstone that is in places at least a thousand feet thick. This sandstone is particularly prominent about Manitou, in the valley of Fountain Creek, and for this reason is called the Fountain formation. This sandstone is of middle Carboniferous (Pennsylvanian) age. A limestone or gray and pink dolomite[24] about 100 feet thick and a sandstone of about the same thickness lie below the Fountain formation. This sandstone rests on the granite of the Front Range. All the rocks below the Dakota sandstone are prevailingly red, and this color is well displayed in the valley west of the hogback.

At Burnito siding may be seen some of the canals that carry water to irrigate the valley below, as well as the pipe line which supplies Canon City with water. The pipe line is high up on the north (right), and the water is carried by gravity into a settling reservoir, which may be seen on a hill to the right. Below the city aqueduct is a canal, which is taken by a tunnel through the hogback to irrigate the orchards on the north side of the valley. On the south there are two canals, one high up on the hillside and one near the level of the river bottom. The higher canal receives its water from Grape Creek, which enters the river just at the edge of the mountain; the lower one takes water from Arkansas River near the mouth of this creek.

A short distance above Burnito siding the traveler is face to face with the imposing portal of the Royal Gorge. (See Pl. XXXIII, *B*.) On the left is the old Hot Springs Hotel, now abandoned, and on the right and considerably above the railroad are some small tunnels through which the city pipe line is carried. The passage seems almost barred by the great slab of gneiss which projects from the north and stands 400 or 500 feet high. The traveler may imagine that the train will at once plunge into the shadowy depths of the mighty gorge, but after passing the portal he finds that the canyon, though rocky, is not particularly rugged or precipitous.

The observant traveler will soon notice that there is close connection between the character of the rock and the shape and narrowness of the gorge. Where the rock is massive granite cut by few joint planes the gorge is narrow, but where the rock is intricately banded and composed of many layers of diverse appearing rocks it is wider and the slopes are more gentle. The differences in the form and width of the canyon are due to differences in the resistance which the various kinds of rock have offered to the cutting power of the stream and to the processes of weathering.

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[24] A dolomite is generally regarded as a limestone, but a limestone consists essentially of carbonate of lime, and a dolomite of double carbonate of lime and magnesia, containing 55 to 65 per cent of carbonate of lime and 35 to 45 per cent of carbonate of magnesia.

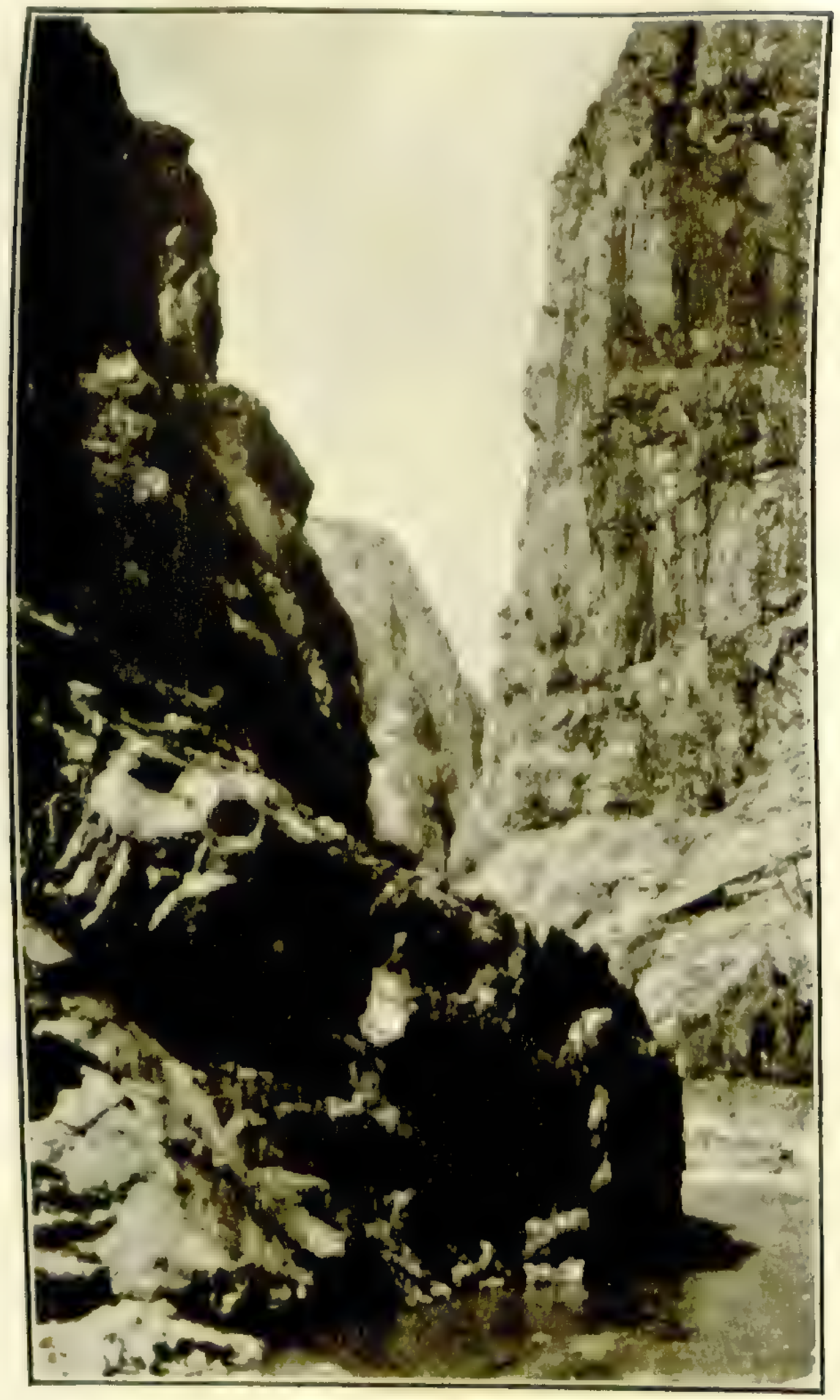
Although the rocks throughout the Royal Gorge are in general similar, they differ greatly from place to place, their character depending largely on the crushing stresses to which they have been subjected at great depths in the earth. In some places the rock is massive granite; it has never been crushed or disturbed in any way. In other places the rock (probably originally granite, or possibly sandstone and shale) has been so squeezed and crushed that it has been more or less changed. The minerals of the rock have been recrystallized, and in the process of change the crystals have been arranged in layers at right angles to the direction in which the force was applied, and the rock has become a gneiss. In some places the process has been carried so far that all the rock material has been recrystallized, and the rock has become an exceedingly soft mica schist, composed largely of small flakes of mica, and it can be split like a slate. The structure is complicated also by dikes, which cut across the other rocks, or irregular intrusive masses which here and there break up the regularity of the banding. In places veins of quartz have been deposited from mineral-bearing waters that slowly circulated through open fissures. Finally all these masses have been turned and twisted, folded back upon themselves, and broken, until the result is a structure which is complicated almost beyond description.

As the train moves on the canyon walls grow higher and somewhat steeper, and through a side gulch here and there the traveler may catch glimpses of the most rugged towering pinnacles. Such a view may be obtained about half a mile above milepost 164, up a small canyon on the right to a wall of massive granite that stands at least 1,000 feet high.

At the abandoned station of Gorge the Royal Gorge really begins. Below this point the railroad has had little difficulty in finding a passage, but immediately above the old station the walls close in until the stream has a width of barely 50 feet. The walls are massive and rise nearly vertically to heights of 1,000 to 1,200 feet. (See Pls. XXXVI, *A*, and XXXVII.) The train here plunges into the vast depths of this narrow cleft, and the traveler is free to enjoy the scene, without a thought as to how or where he is to emerge from them. He knows that he will be through the canyon in a few minutes, but the early explorers had no such knowledge. Lieut. Pike, who visited the Royal Gorge about the first of January, 1807, had serious difficulty in exploring its narrowest parts. Can anything more difficult be imagined than that attempt to find a passage through this unexplored gorge at a time of the year when the water was ice-cold?

Gorge.

Elevation 5,494 feet.
Denver 165 miles.



A. MASSIVE WALLS OF THE ROYAL GORGE.

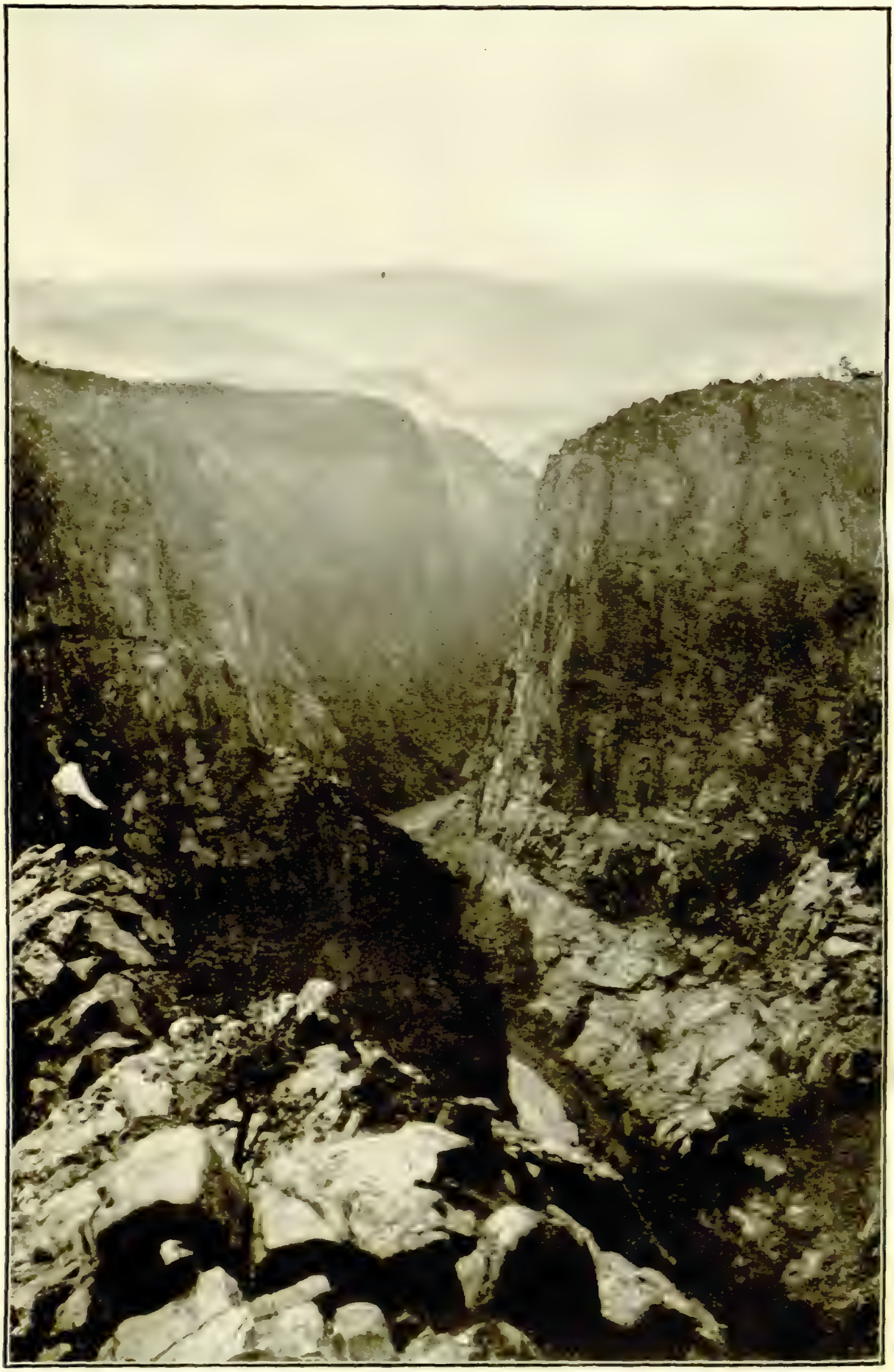
View up the canyon from the train near the old station of Gorge. The massive wall on the right is shown also in Plate XXXVIII. The water pipe to Canon City tunnels the projecting point on the left. Photograph by Marius R. Campbell.

B. FOREST OF LODGEPOLE PINE.

This tree grows remarkably straight and tapers from base to top. In a mature forest few trees exceed 12 inches in diameter. The young trees are prized by Indians for tepee or lodge poles. Photograph by U. S. Forest Service.

C. GRAND CANYON OF THE ARKANSAS.

Projecting point on the south wall above Cotopaxi and the new Rainbow Highway at the base of the cliff. Photograph by Marius R. Campbell.



VIEW LOOKING DOWN INTO THE ROYAL GORGE.

When one stands on the rim above the old station of Gorge and looks down into this great chasm the railroad looks like a thread stretched beside the foaming stream. The point of the rim ordinarily reached by travelers is around the bend to the right. The lowland in the distance is at Parkdale, and the gap in the range beyond is the mouth of the river canyon that extends upstream to Cotopaxi. Photograph furnished by the Denver & Rio Grande Western Railroad.

At Gorge the Canon City pipe line crosses the river. In rounding the next point on the right the traveler may see above him one of the most massive walls in the canyon. It is probably 1,200 feet high and is nearly smooth as far as one can see. After passing around this projecting mass into the next bend the traveler on looking ahead may see people on the crest of the wall, for the automobile road from Canon City leads to this point. The wall upon which they stand is about 1,100 feet [25] above the railroad, but the rock is so massive that it is difficult to appreciate its great height. At milepost 166 the traveler is directly below the point reached by the automobile road, and he may obtain some idea of the immensity of the gorge, but the view from the bottom, though interesting, does not compare in grandeur with the view to be obtained from above. One is more accustomed to looking up at great heights than to looking down into great chasms, and the canyon is therefore less striking when seen from below than from above.

The train swings around the base of the overhanging walls of the point on the right and crosses the Hanging Bridge (Pl. XXXVIII) in the narrowest part of the gorge. In places here the walls actually overhang, but pictures of the gorge taken from this point have been so widely circulated that almost everyone, even before reaching Colorado, is familiar with them. The engineering feat of hanging a bridge from the walls of the canyon instead of supporting it by abutments is of course novel and attracts much attention, but few who pass over the road think of the engineers who made the first location for the road or of the workmen who hewed their way through the solid rock. It is reported that at some of the construction camps men and tools and mules and carts were let down the canyon wall by ropes; that the engineers made their locations on the ice or while struggling through the icy waters; and that the rockmen were hung suspended in the air while they drilled the holes in the granite and fired the blasts that sent tons upon tons of rock crashing into the stream below. If the experiences of these men could be written the story would abound in thrilling moments of suspense and hairbreadth escapes that would rival the scenes shown in the most realistic moving picture.

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[25] Many figures have been given for the depth of this canyon, but all appear to be only guesses. The favorite figure seems to have been 2,600 feet, or approximately half a mile. The writer, believing that the public is entitled to know the truth about such striking scenic features, requested that the height of the cliff be determined. Accordingly, D. E. Winchester, of the United States Geological Survey, with telescopic alidade and plane table, measured the vertical distance from the base to the top of the cliff and found it to be approximately 1,100 feet. This measurement may be in error as much as 4 feet but probably not more than that.

As already stated, the narrower and more rugged parts of the Royal Gorge are cut in the harder rocks. This fact is well illustrated near the Hanging Bridge, for here the walls are vertical because the great joint cracks that cut the granite are vertical. Whenever a piece of rock is split from the walls it breaks off along one of these vertical joints, and the stream has difficulty in undermining a wall that is composed of huge blocks of rock set on end or rather that have one end deeply buried below water level. The great open fissures along some of these joints give picturesque detail to the walls; the best known fissure is one on the right that can be seen to advantage by looking back just after passing the Hanging Bridge. This crack is 20 feet wide, and down it flows a stream of water which in the driest season yields cool water to the thirsty traveler who may be enjoying a tramp through this great highway. The traveler will doubtless see many other cracks almost as strongly marked as this one at different places in the canyon walls. Many of these fissures have been cleaned out by small streams of water, leaving crevices only a few feet wide, which in many places slope under the overhanging rock for long distances.[26]

[26] Doubtless many persons who have passed through the Royal Gorge have wondered what agent produced this deep and narrow cleft. The question may not often have been voiced, but scarcely anyone can see a chasm so tremendous without wondering how it was formed. The answer which the traveler will get to such a question depends upon the person making the reply. If it is a geologist he will say that the river has excavated the canyon, cutting away the rock grain by grain; but if the question is answered by one who has not made a study of such problems he will probably scout such a proposition and say that it is impossible for a river to cut a hard rock like this gneiss and that the gorge is due to a great fissure that was opened by an earthquake. This view is most commonly held by those who are unfamiliar with the work of streams and was even held by many geologists less than a century ago.

It is comparatively easy to prove that the Royal Gorge was not formed by an earthquake, for, first, the gorge is too crooked to be the result of a fissure and, second, the bands of rock can be traced practically from wall to wall across the canyon. There is no possibility of a break such as would be required by the earthquake hypothesis. Altogether the evidence is conclusive that the Royal Gorge and most other canyons are not earthquake fissures but were cut by the streams that occupy them.

The cutting power of water depends on the amount of sand and gravel which the stream is able to carry or to roll along on its bottom. Clear water may dissolve the rocks, but it has no cutting power. Water loaded with sand cuts the rocks by the scouring action of the grains of sand on the rocks over which the water flows. It acts much like a sand blast, and no rock is so hard that it can withstand the constant grinding of grains of sand. According to human standards the process is very slow, but it is almost constantly in operation, day and night, and eventually it will make its work apparent.

HANGING BRIDGE, ROYAL GORGE.

The Hanging Bridge, in the narrowest part of the canyon, is a striking feature. When the road was built there was not room at this point for both river and railroad side by side, so a bridge was necessary. The easiest way to construct such a bridge was to use the two walls of the canyon as abutments and to swing the bridge from trusses, as shown in this view. The joints in the granite are nearly vertical, and consequently the walls have little backward slope. Photograph furnished by the Denver & Rio Grande Western Railroad.

UPPER END OF THE ROYAL GORGE.

The traveler on the rim of the canyon can climb down, if he has a steady head, to the jagged point shown on the left. Here he can look on the Hanging Bridge and the railroad trains as they thunder through the canyon, waking the echoes from every angle of its mighty walls. The rocks here are much more highly jointed than they are lower down, and as a result the canyon walls begin to have an appreciable slope and to decrease in height. Photograph furnished by the Denver & Rio Grande Western Railroad.

A short distance above the Hanging Bridge, as shown in Plate XXXIX, the walls diminish in height and the canyon opens and bears little resemblance to the narrow gorge just below. About three-quarters of a mile above milepost 166 the slopes are so gentle that they can be scaled, and a trail leading to the top turns up the slope on the north (right). In this part of the canyon the walls are not composed of massive granite or even gneiss, as at most places below, but the rock is a schist, composed largely of flakes of mica that may be recognized by the manner in which they glisten in the sunshine. This mica schist is very soft, compared with the granite and gneiss, and therefore weathers more rapidly, so that the canyon is wider and has smoother and gentler slopes.

Just beyond milepost 168 are the headgate and settling tanks of the Canon City waterworks. In this vicinity the gray granite is cut by a great many dikes of pink feldspar (pegmatite). The crystals of feldspar are large, and their brilliant faces attract attention, especially when the sun is shining on them. In some places these dikes are so numerous and so large that they make up the bulk of the rock and give it a strong red color. The pink feldspar is very abundant in the rock from the siding called Sample to the edge of Webster Park, near Parkdale.

Toward the west the hills grow smaller and the canyon less pronounced, until finally, in making a sharp turn to the right just before reaching milepost 170, the traveler catches on the left a glimpse of an open valley of considerable extent, which comes as a pleasing contrast to the frowning walls of the deep canyon. This open valley is Webster Park, one of the beautiful natural parks which diversify the mountain scenery of Colorado. The surface of Webster Park is underlain by soft sedimentary rocks that have been downfolded or dropped by some fault, thus being preserved from complete destruction by erosion.

The first sedimentary rocks that can be seen from the train are on the right. They are the variegated shale and sandstone of the Morrison formation, and above them lie the more somber sandstones of the Dakota. These beds of rock lie nearly horizontal, but doubtless their contact with the granite, if it could be seen, would show that they rise gently toward the east at about the same rate as the surface of the granite on which they were deposited. The traveler may be surprised to find the Morrison formation in Webster Park in contact with the granite, whereas at Canon City several hundred feet of beds lie between the Morrison and the granite. The absence of these underlying formations in Webster Park is probably due to the fact that the upper surface of the granite was for a long time a land surface and upon this land the sedimentary beds were deposited

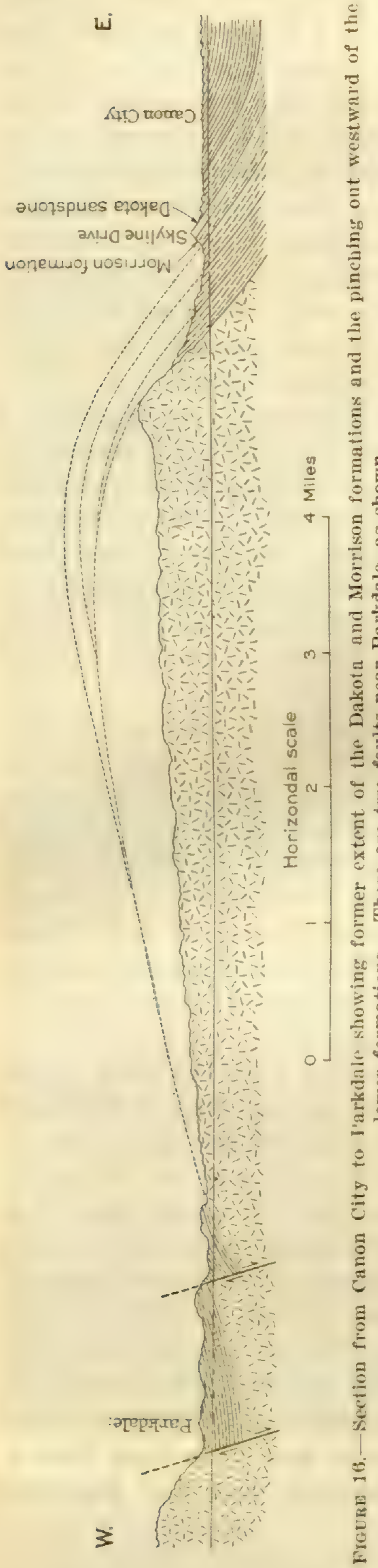


FIGURE 16.—Section from Canon City to Parkdale showing former extent of the Dakota and Morrison formations and the pinching out westward of the lower formations. There are two faults near Parkdale, as shown.

at different elevations before the granite was arched and broken by faults, as shown in figure 16. Thus the lowermost formation at Canon City may have originally extended onto the granite a mile or so and the next one 2 or 3 miles, and so on, until finally, when the Morrison was deposited, the entire area was low, and the Morrison beds were laid down continuously from Canon City to Parkdale.

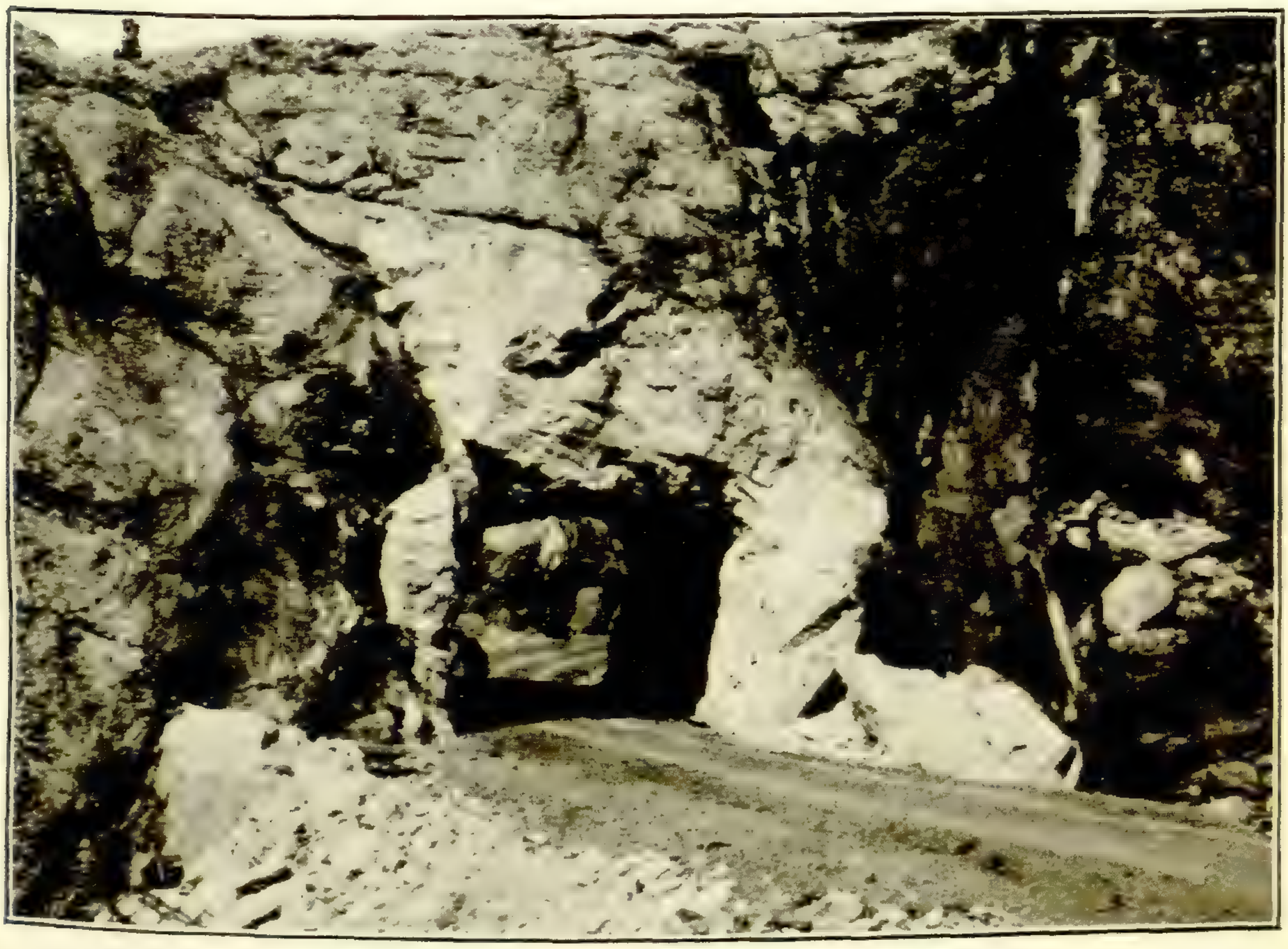
West of milepost 170 the beds dip sharply toward the west, as shown in figure 16, and the Dakota disappears under the dark shale of the Benton. About 1,500 feet beyond milepost 170 the shale is in contact with the granite, which shows that they must have been brought into this abnormal relation by a fault that dropped the shale on the east as compared with the granite on the west. This relation of the shale and the granite is illustrated in figure 16.

Beyond this fault the hill on the north (right) of the railroad is composed entirely of granite, but on the south the variegated shale of the Morrison rests on the granite just as it was deposited ages ago. At the point where the railroad crosses Tallahassee Creek the Morrison outcrop swings to the north, and a hill composed of this formation, capped by Dakota sandstone, which dips toward the west, may be seen half a mile away. The sedimentary rocks can not continue in this direction much farther, for the granite, which can be seen on the north, makes a high rim completely around the valley.

The rock in the middle of the valley is concealed by a deep cover of gravel, which the river has evidently brought down from the high

A. GRAND CANYON OF THE ARKANSAS BELOW TEXAS CREEK.

Below Texas Creek the canyon in many places is very rough and rugged, the massive granite projecting from the walls on either side seems almost to bar the pathway of the river, and these spurs are crowned with crags and pinnacles. Photograph by Marius R. Campbell.



B. TUNNEL ON RAINBOW HIGHWAY.

The construction of the Rainbow Highway involved engineering difficulties as great as those which beset the railroad engineers in 1881. Much rock cutting was done, and even tunnels were driven through the projecting points of massive granite. Photograph by Marius R. Campbell.

A. GOLD DREDGING.

Great dredges like those used in deepening harbors and in excavating the Panama Canal are set to work in the heart of the Rocky Mountains, digging up and washing gravel for the gold it contains. This view shows the great heap of washed gravel that is left in the wake of the dredge. Photograph by F. L. Ransome.

B. RAINBOW HIGHWAY.

Automobiles now traverse the grand canyon of the Arkansas as readily as railroad trains, owing to the recent completion of the Rainbow Highway from Parkdale to Leadville. In many places the cost of construction was as great as that of the railroad on the opposite bank. Photograph by the U. S. Forest Service.

mountains farther west. One of the striking features of this gravel-covered terrace is the great number of big boulders that litter the ground around the station at Parkdale and for some distance to the east. These boulders are composed of all sorts of rock from the high mountains and range from mere gravel stones of the size of a marble up to boulders 10 or 12 feet in diameter. These large boulders have certainly been brought down the river valley, but by what agency? Could water have transported them? At first sight it would seem impossible for water to move boulders of this size through a canyon and then spread them out in a great fan nearly a mile long, but there seems to be no other agent by which they could have been transported. Some may suggest that possibly the glaciers of the Ice Age may have extended down as far as Parkdale and carried the boulders and dropped them where the ice melted. It is well known that glaciers do carry such boulders, but a glance at the rugged walls of the canyon above Parkdale (see Pl. XL, *A*) will soon convince the traveler that no glacier has ever moved down this canyon. Water, therefore, is apparently the only agent that could have transported these boulders.

Just as the train emerges from the canyon into Webster Park it crosses the Rainbow automobile road, which was last seen at Canon City. It was manifestly impossible for this road to follow the river through the Royal Gorge, so it takes a more circuitous route to the north and then returns to the river in Webster Park. Here it crosses to the south side of the river and follows that side until the river emerges into the broad valley at the foot of the Sangre de Cristo Range[26] above Cotopaxi. The construction of this road through the canyon above Parkdale involved a large amount of rock work, and the State and county deserve to be congratulated on its completion. (See Pls. XXXVI, *C*; XL, *B*; and XLI, *B*.)

Webster Park is an oasis of valley land in a wilderness of mountains. Near the river some of the soil is too gravelly for farming, but back from the river there are good farms. Stock raising is the principal occupation, and the cattle find good summer pasture upon the mountain slopes.

Parkdale.

Elevation 5,800 feet.
Population 87.*
Denver 171 miles.

At the station of Parkdale the traveler, on looking back, can see the low range of mountains, or rather the plateau, in which the Royal Gorge is cut.

About Parkdale the dark shale of the Benton shows in a number of places below the gravel, and the next rock that is seen in passing westward is the granite at the mouth of the canyon. It is therefore certain that no hard rocks, such as the Dakota sandstone, are present

[26] Spanish term meaning "blood of Christ," pronounced sahn'gray day cris'to.

between the Benton shale and the granite, and the shale and the granite must be brought into contact by a fault, as shown in figure 16.

Above Parkdale the river is again confined in a narrow, rugged canyon, which has been cut in a plateau similar to that in which the Royal Gorge is cut. (See Pl. XXXIV, *A*, p. 72.) Upon this plateau there are several ranges of mountains, which rise to elevations of 12,000 to 14,000 feet above sea level and which are included in the San Isabel National Forest. This forest furnishes excellent summer pasture for a large number of cattle and sheep, which are driven into the mountains each spring from ranches in the lowland on both the east and the west. The forest is also an effective conserver of water, for in it lie the heads of a number of streams that supply water for domestic use and irrigation to the cities, towns, and ranches of the plains. It is a haven of refuge for wild animals, particularly deer, which thrive upon its excellent pasture lands. The fawns are almost as tame as the lambs which gambol about their mothers in the deep grass. (See Pl. XLII, *B*.)

In the Greenhorn Mountains many summer homes have been built by the citizens of Pueblo and connected with that city by fine automobile roads. The use of the national forests for recreation is encouraged by the Government, and in many localities sites suitable for summer homes have been mapped and laid off in lots so as to be available to those who wish to avoid the crowded cities during the heat of summer. The charge for building permits ranges from $10 to $25 a year, depending on the accessibility and attractiveness of the site. Logs and poles for building and wood for fuel may be procured free of charge under permit from the local forest officers. One of these summer homes is shown in Plate XLII, *A*.

The canyon above Parkdale, although it is generally considered with the Royal Gorge as constituting the grand canyon of the Arkansas, is really a separate canyon. It has a length of about 24 miles, measured along the railroad, and may be divided, according to its width and the ruggedness of its walls, into three parts, two of them narrow and rugged and the third, separating the more rugged parts, broad and more or less smooth.

The first part of the canyon extends from Parkdale to Texas Creek, a distance of 11 miles. This canyon is not so narrow nor so deep as the Royal Gorge, but it is nevertheless picturesque and well worthy of close attention, particularly as it can generally be seen from an open observation car. The charm of this canyon is the variety of its scenery. In places it is narrow and has steep and rugged walls; in others it is relatively broad, though here and there projecting points of rock have been cut by the stream into nearly vertical cliffs. In other words, this canyon looks as if it

A. SUMMER HOME IN A NATIONAL FOREST.

The United States Forest Service leases ground, under certain restrictions, for summer homes in the national forests. This is such a home in the San Isabel Forest, south of Arkansas River. Photograph by the U. S. Forest Service.

B. GAME IN A NATIONAL FOREST.

Deer soon become plentiful when they are protected. The wild fawn shown here was photographed in the San Isabel National Forest by the U. S. Forest Service.

HOWARD AND THE SANGRE DE CRISTO MOUNTAINS.

From Howard there is a magnificent view of the Sangre de Cristo Range, especially when the mountain tops are covered with snow. The highest point in this part of the range is Hunts Peak, 12,140 feet above sea level, which shows at the right of the picture. The valley was once deeply filled with gravel from the mountains, remnants of which can be seen in the long terrace on the farther side of the river. Photograph by Henry R. Hay, Salida.

had been occupied by the stream for a longer time than the Royal Gorge.[27]

Texas Creek.
Elevation 6,210 feet.
Population 63.*
Denver 184 miles.

The walls of the canyon from its mouth just above Parkdale to Texas Creek are generally uniform in height, so that this canyon also appears to have been cut in a plateau, the surface of which was originally gently rolling. At Texas Creek a branch of the railroad turns to the south (left), crosses the river, and after running up a small valley for a short distance in order to obtain grade, turns back and loops around a projecting spur considerably above the bottom of the valley. After passing this spur the road follows for a long distance the valley of Texas Creek on its way to the mining district of Westcliffe, 25 miles distant.

Near the station of Texas Creek the canyon takes on a different aspect. It becomes much broader than it is east of that place, and though the walls may in places be precipitous, they are generally smoother and gentler in their slope than they are farther east. This part of the canyon looks older than the part below, and it is also different from the part above. On leaving Texas Creek the train heads directly toward the great Sangre de Cristo Range (*Pl. XLIII*) and at a point 3 miles above Texas Creek swings abruptly to the right, following Arkansas River, which here leaves the broad valley in which it has been flowing, and in a short distance it again enters a canyon, some parts of which are steep and narrow. If the traveler looks to the left as the turn is made he will see that the broad valley continues directly toward the high mountain peaks but is occupied only by Oak Creek, a stream not at all commensurate in size with that of the valley which it occupies. The meaning of these differences

[27] Geologists generally classify the surface features of the earth according to their age or according to the length of time they have been in the process of formation. Thus there may be young mountains and old mountains, young valleys and old valleys, and young streams and old streams. Where the rocks are fairly uniform throughout, the youngest type of valley is the canyon and the oldest is the broad valley with slopes so gentle that it almost resembles a plain. A canyon is considered young because it marks the first stage in valley cutting; a broad valley is considered old because it marks its last stage. Although all canyons are young, they may differ considerably in age, so there are young canyons and old canyons. In canyons of these two classes that are cut in essentially the same rocks young canyons may be distinguished by the narrowness of the bottoms, which are generally but little wider than the channel of the stream, and by having walls that are commonly steep and in many places precipitous. Old canyons, on the other hand, are generally wide enough, at least in places, to have narrow strips of flood plain; their walls are less precipitous, and their rocks are generally more irregular in outline owing to the fact that they have been longer exposed to the weather.

in the character of the canyon of the Arkansas is not yet understood, but it could probably be satisfactorily explained if the history of the river were thoroughly known.

Above the mouth of Oak Creek the canyon of the Arkansas for some distance is irregular in width and the sides are low, indicating considerable age, though it is generally narrow, and farther on it becomes more precipitous, until in the vicinity of Cotopaxi it is a veritable canyon, though it is wider than the part of the canyon below Texas Creek.

Cotopaxi is a small settlement, hemmed in on all sides by high granite walls, but fairly good roads lead from it southwestward to a rich agricultural region at the foot of the Sangre de Cristo Range.

Cotopaxi.

Elevation 6,385 feet.
Population 252.*
Denver 192 miles.

Small quantities of the precious metals as well as some copper have been found near the town, but none of the mines are now in operation. Limestone was once quarried here in large quantities for use as flux in iron furnaces, but most of the limestone now so used at Pueblo is quarried near Howard, farther up the valley. The quarries near Cotopaxi were about 3 miles north of the railroad, at the southern end of the belt of Carboniferous rocks. (See sheet 3, p. 100.) The limestone has been preserved here by being downfolded into the granite, and on the east side of the downfold the rock has been broken by a fault and replaced by the granite.

For some distance west of Cotopaxi the sides of the canyon are composed of massive granite, which in places stands up in nearly vertical walls (see Pl. XL, *A*), but the valley bottom is generally wide enough to afford ample accommodation for the railroad and for the Rainbow Highway. The canyon maintains this width for some distance, but beyond milepost 194 the river passes through the narrowest and most rugged part of the canyon west of Parkdale.

About three-quarters of a mile beyond milepost 194 the railroad emerges suddenly from the granite canyon into a broad valley at the foot of the Sangre de Cristo Range. The course of the railroad, which for a long distance has been nearly southwest, here veers to the northwest along this valley. The change from seemingly endless vistas of rocky canyon walls to a broad valley in which there are farms and green trees is striking and exceedingly restful and is one of the surprises that are constantly awaiting the traveler in this mountainous region.

The change in scenery and in the general character of the country is due to a difference in the underlying rocks, but for some distance this fact is not apparent, as the rocks are not visible from the train, the land near the river being composed of sand and gravel washed

GEOLOGIC AND TOPOGRAPHIC MAP

OF THE

RIO GRANDE ROUTE

From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
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M. R. CAMPBELL, Geologist
C. H. BIRDSEYE, Chief Topographic Engineer
A. C. ROBERTS, Topographer

1922

EXPLANATION

		Age	Thickness in feet
B	Gravel on mesas and terraces	Pleistocene and late Tertiary	
D	Arkosic (fragments of granite) conglomerate (Dawson arkose)	Tertiary (*Eocene*)	300
G	Sandstone and shale with coal beds (Laramie formation)	Upper Cretaceous	1,200
I	Dark marine shale with sandstone at top (Montana group) — Fox Hills sandstone / Pierre shale	Upper Cretaceous	3,000
J_1	Dark marine shale and limestone (Colorado group)*	Upper Cretaceous	1,000
K (a)	Calcareous shale and limestone (Niobrara formation)	Upper Cretaceous	600±
L (b)	Shale, limestone, and sandstone — Carlile shale / Greenhorn limestone / Graneros shale	Upper Cretaceous	400
M	Two sandstones separated by shale — Dakota sandstone / Purgatoire formation	Lower Cretaceous	400
N	Red and green shale and sandstone (Morrison formation)	Cretaceous?	225±
T	White and red sandstone, red shale and gypsum at top; Red arkosic sandstone and conglomerate (Fountain formation) — Lykins formation / Lyons sandstone	Carboniferous (*Permian (?) and Pennsylvanian*)	5,000
U	Limestone and quartzite — Millsap limestone / Fremont limestone / Harding sandstone / Manitou limestone / Sawatch sandstone	Carboniferous (*Mississippian*) / Ordovician / Cambrian	490±
X	Granite	Pre-Cambrian	
Y	Lava flows (rhyolite and basalt breccia); Andesitic breccia and tuff	Tertiary	
	Fault		

* *The Colorado group is subdivided into two parts, (a) and (b), in the southeastern part of the area; in other parts the outcrop is too narrow to make such a subdivision practicable*

down from the high mountains at the back of the valley. The railroad follows the east side of the river, passing by the village of Pleasanton and hugging the granite cliffs that border the valley on the northeast (right). The contact of the soft rocks of the valley with the granite or gneiss is not a normal contact but is due to a fault, the granite having been elevated or the other rocks depressed an unknown distance.

Pleasanton.

Elevation 6,481 feet.
Denver 196 miles.

In order to understand the meaning of the surface features along the railroad from Pleasanton to Salida it is necessary to know the geologic structure and the succession of hard and soft rocks.

Mountains are usually formed either because they contain rocks that are somewhat harder than the rocks in adjacent areas or because recent disturbances in the earth's crust have raised one part of the crust with relation to another; or they may be formed by

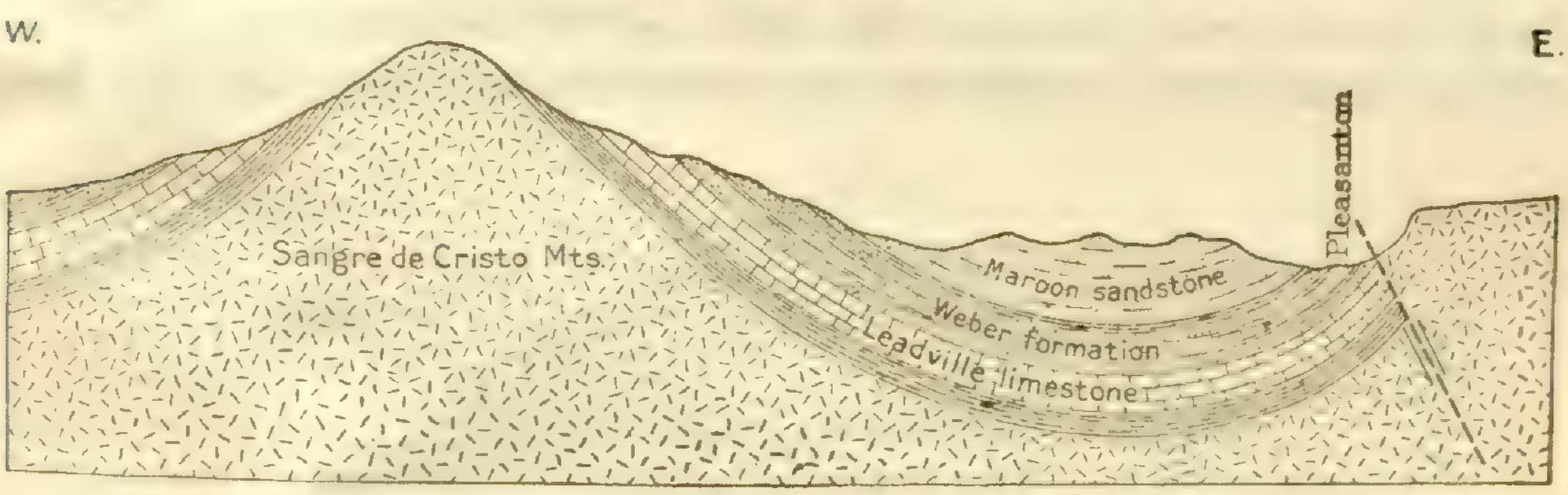

FIGURE 17.—Cross section of the Sangre de Cristo Range and the valley on its east side at Pleasanton, showing the anticline of the mountain and the syncline on the east.

volcanic action. In the Rocky Mountains the principal ranges and peaks have been formed by one or both of the two causes first stated.

The great Sangre de Cristo Range, which towers on the left a mile above the railroad, is no exception, but this range, unlike many others of this general region, is very narrow, being at no point more than 12 or 15 miles wide. At many places its crest is composed of granite and gneiss, which, being harder than the surrounding rock, have remained at their present height, while the softer rocks on either side have been washed away to lower levels. In general, the structure of the mountain at the north end is that of a great anticlinal fold (arch), mainly in Carboniferous rocks, though it affects the lower rocks down to and including the granite. At a point farther south the fold crosses the range at a low angle, and from that point southward the structure is entirely different. The section shown in figure 17 represents in a general way the structure of the rocks at the north end of the mountain—the anticline in the moun-

tain and the syncline (trough) on its east side. From a point above Howard to Pleasanton Arkansas River flows in the valley eroded in this syncline, and the granite on the right of the railroad lies on the east side of the fault, as shown in the section.

At Pleasanton the railroad is built on the Weber shale and sandstone near the fault, but in passing northward it diverges more and more from the granite wall until it is on the Maroon sandstone nearly in the middle of the trough. This sandstone makes its appearance a short distance above the siding of Vallie. It is very conspicuous on the left, in the hill across the river, and dips about 70° W., or into the great syncline which lies on that side of the railroad. This hill shows to good advantage not only the red Maroon sandstone but a cap of lava, which gives some clue to the recent geologic history of the valley. As seen from the train the lava cap appears to be horizontal, but after passing it the traveler, upon looking back, may see that the lava cap is underlain by a bed of white volcanic tuff [28] about 40 feet thick and that both the lava and

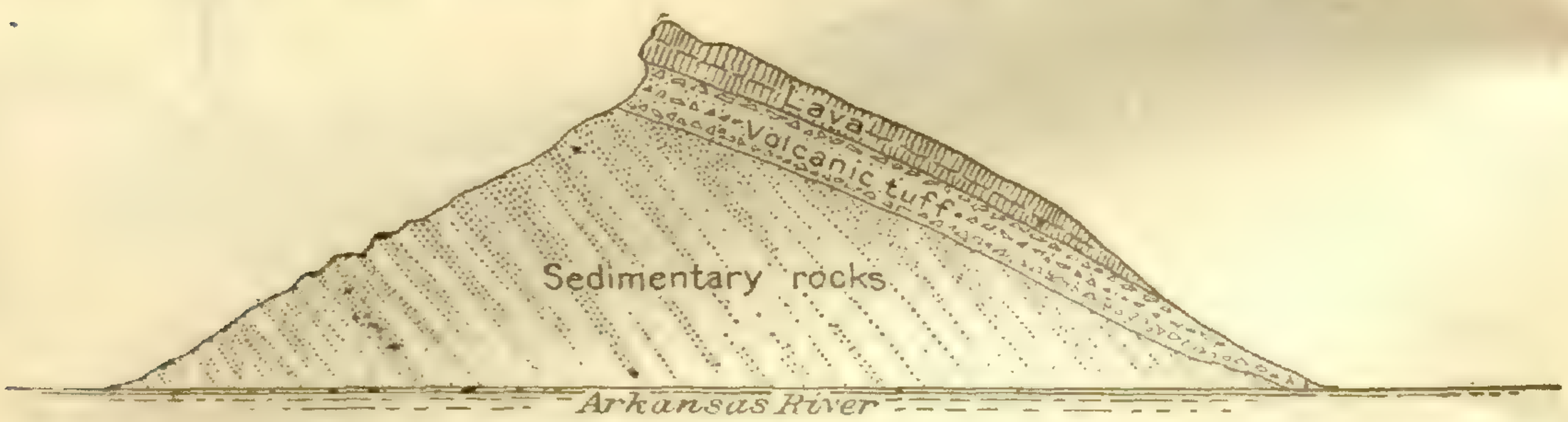

FIGURE 18.—Lava-capped hill south of Howard. The hill, which is opposite milepost 200, is composed of red sandstone dipping steeply to the northwest and is capped by a nearly horizontal sheet of tuff and lava.

the tuff slope to the west, or away from the railroad, as shown in figure 18. This westward slope shows that at the time the tuff was deposited and the lava was poured out upon its upper surface, the deepest part of the valley lay considerably west of the channel in which the river flows to-day.

The red sandstone crops out by the side of the railroad as far as milepost 200. Here it is covered by a large mass of tuff and lava which descends below river level and which shows on the northeast side of the valley in places to points beyond Howard. Most of the high hills near Howard are capped with white volcanic tuff and with a sheet of lava, which invariably slopes to the west. These

[28] Volcanic tuff is a name applied to material blown out of a volcano by an explosion of gas or steam. It is generally composed of fine particles of glass but may include fragments of rock of different sizes. The bed of tuff here may have been formed of dust and ashes that settled down on the ground from the atmosphere or were washed into a basin or valley.

rocks have been traced eastward to a point near the fault at the edge of the granite. As the lava rises steadily toward the east the volcanic vent from which it came was probably near the fault and on high ground, thence it flowed westward down the slope to the river, which was then farther west and somewhat lower than it is to-day.

The volcanic matter doubtless partly filled the old valley of the Arkansas, and then came a great wash of gravel and boulders from the mountains, which must have filled the valley to a depth of several hundred feet. No one yet knows what caused this great deposit of gravel, but it has been assumed to have some connection with the formation of great glaciers in the neighboring mountains. This influx of foreign material dammed the river and forced it over to the east side of its valley, entirely out of its former position. At present the river is cutting away the gravel and lava, but it has not yet cut down to its former level. Remnants of the gravel filling may be seen in the extensive terraces opposite Howard, as shown in Plate XLIII.

At Howard a branch railroad turns to the left, crosses the river, and disappears in the hills in the distance. This line runs to a stone quarry at the station of Calcite, where limestone is being quarried on a large scale by the Colorado Fuel & Iron Co. for use as flux in its large blast furnaces at Pueblo. Howard is a small village, but the well-cultivated farms across the river indicate a prosperous community. The land on both sides of the river is irrigated and yields abundant crops of alfalfa and the more hardy grains. Near the station there are kilns in which charcoal was formerly made. (See Pl. XIV, *B*, p. 30.) These kilns are the only traces that remain of what was once a large industry in these mountains. The native timber was used in making charcoal, which was in great demand by smelters in almost every mining town. The concentration of the smelting industry into the hands of large corporations and the consequent abandonment of most of the small plants, together with the increased production of coke in the coal fields near by, killed the charcoal industry. Although the decay of this industry temporarily deprived many persons of the means of making a livelihood, it was a blessing to the region as a whole, for the manufacture of charcoal is a wasteful process and one that has consumed much valuable timber that might have been reserved for a more useful purpose.

Howard.

Elevation 6,718 feet.
Population 479.*
Denver 203 miles.

A little beyond Howard the railroad turns more toward the west and crosses the bedded rocks, which show to good advantage. In

this section (see fig. 19) the syncline has been so squeezed by pressure from the east that its sides have been pressed close together or overturned, and consequently all the rocks dip toward the east. The lava is prominent in this part of the valley, but it is limited to the hills on the opposite side of the river. These hills at first appear to be composed entirely of lava, but close scrutiny will show that the red sandstone crops out here and there near the river level. This low place in the sandstone evidently marked the middle of the valley at the time the lava was poured out and filled the valley to a depth of 300 or 400 feet. West of milepost 205 the railroad crosses Badger Creek, which drains a large territory between the Arkansas Valley and South Park. The red sandstones are well exposed in the bend of the river a little farther on and in the ap-

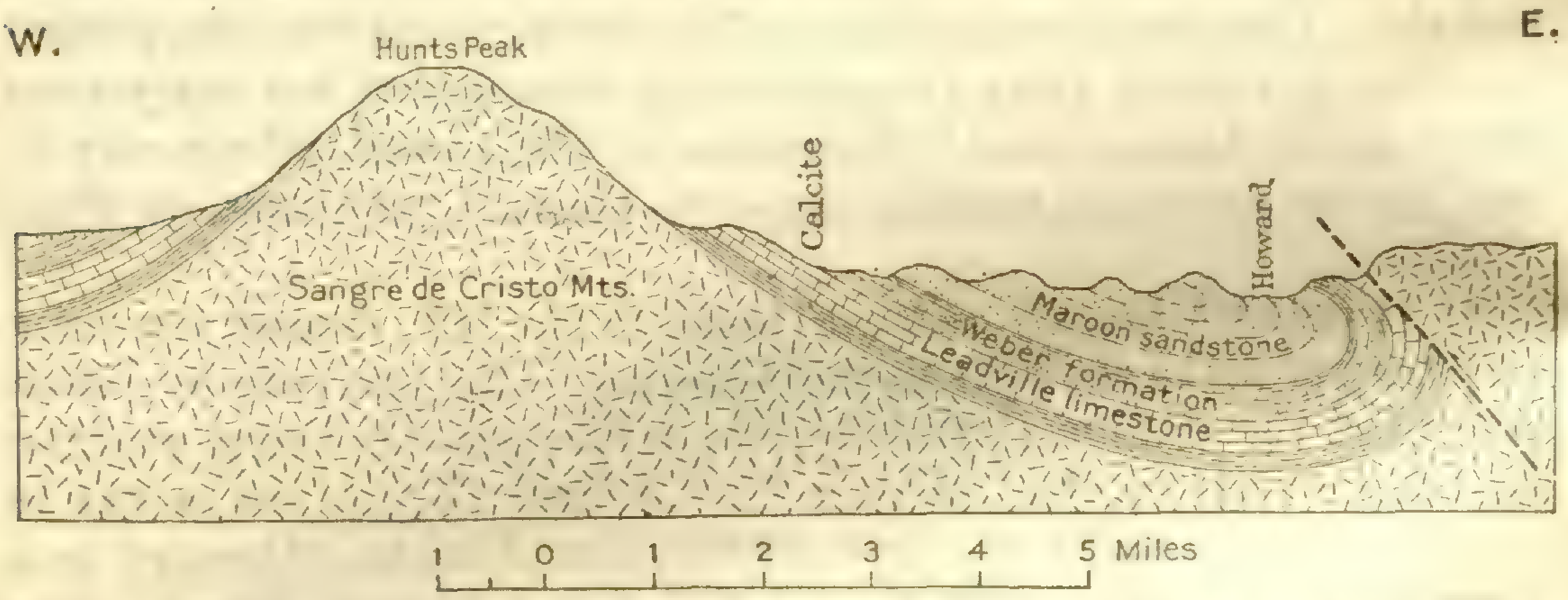

FIGURE 19.—Section of the Sangre de Cristo Range and the valley on its east side, through Hunts Peak and Howard.

proaches to the tunnel beyond milepost 206. They are fairly conspicuous in the river bluffs near milepost 207, but west of this point the red color disappears from both sides of the valley. The last lava-capped hill is nearly opposite milepost 207, and this hill marks the western limit of the old valley, which is now so deeply filled with the volcanic material that it constitutes hills rather than a valley.

Swissvale.

Elevation 6,868 feet.
Denver 208 miles.

At Swissvale the railroad is built upon a broad gravel-covered flat. The absence of exposures of hard rock is due largely to this fact and to the fact that the flat, or rather terrace, is composed of the Weber shale and sandstone, which underlie the red sandstone that is so conspicuous farther east. This relation is due largely to the effect of a cross anticline, which trends in the direction followed by the railroad. This anticline brings the Leadville limestone near the surface, but it can not be seen from the railroad until the train passes Wellsville Springs. Its position is marked on the river bank, however, by numerous springs, which carry so much lime in solution that as soon as they emerge from the bank they deposit the lime

in the form of calcareous tufa, building up domes of this material around the springs. A rather large spring of this kind is being utilized at Wellsville as a bathing pool, making it a general pleasure resort for the surrounding towns.

Long ago, when the river was flowing at a much higher level than it is now, large springs issued along its banks much as the springs issue along its banks to-day, and they built up immense masses of tufa, which now stand several hundred feet above the railroad. This tufa consists of nearly pure carbonate of lime, and it is now being quarried in a large way for use in refining beet sugar and as flux in iron furnaces.

West of Wellsville Springs the sides of the valley become steeper and the railroad is crowded to the bank of the river under a high cliff of Leadville limestone, which is the lowest formation of the Carboniferous system. The beds of rock in this cliff have been greatly distorted by folding and in places stand nearly vertical, but the bedding has been largely obliterated by the solution and redeposition of the lime, so that the structure can not be determined from the train. After passing the great bend of the river to milepost 210, the synclinal structure may be plainly seen in the bluff on the far side of the river.

The limestone is conspicuous on both sides of the valley almost to milepost 211, where it rises and disappears in the tops of the hills. It is underlain by thin-bedded quartzite, the age of which is not definitely known, though it is considerably older than the other sedimentary rocks which the traveler has recently seen. The quartzite is so much changed by movement and pressure in the crust of the earth that at first sight it may not be recognized as a sedimentary rock. It is cut off in a short distance by a great mass of intrusive rock, which occupies a large area on the northeast side of the river valley and extends up the river as far as the stockyards 2 miles below Salida. Beyond this place the intrusive rocks are restricted to the northeast side of the river, or if they occur on the other side they have been dropped so low by faulting that they are effectually concealed by the gravel in the bottom of the valley. The Arkansas Valley above Salida has doubtless in many places been affected by faulting, so that large tracts have been dropped hundreds and possibly thousands of feet and the depressions so produced filled with sand, gravel, and boulders brought down from the great Sawatch Range on the west. About Salida in particular the evidence of such a dropped block seems to be conclusive, for the river a few miles below the town is flowing on bedrock and it would still be running on or near bedrock at Salida had the bedrock not been depressed below its original level.

The largest town in the mountains west of Canon City is Salida (from the Spanish word outlet; locally pronounced sah-lie'da), which was so named because it stands at the outlet of the upper Arkansas basin. It was settled in 1880 at the time the railroad was being built up the Arkansas Valley, and it is at the junction of the narrow-gage road over Marshall Pass to Grand Junction and that over Poncha Pass to San Luis Park with the main line of the Denver & Rio Grande Western Railroad. Here are the repair shops of the railroad and some other manufacturing plants, and a mile northwest of the town there is a large smelter. It is a town of homes, but in addition there are several hotels for the accommodation of travelers who change from one route to another in order to see the beautiful scenery for which this region is noted. The town lies in a basin that is nearly surrounded by mountains. (See Pl. XLIV.) The Sangre de Cristo Range, which begins near Santa Fe, N. Mex., terminates just south of the town in a prominent point known as Hunts Peak (12,446 feet). The Sawatch Range begins in Mount Ouray (13,955 feet), a little west of the north end of the Sangre de Cristo Range, and stretches northward, including Mount Chipeta, Mount Shavano (14,179 feet), and other high peaks, shown in Plate XLIV. To the north and northeast there is a jumble of lesser ranges without special names.

Salida.

Elevation 7,050 feet.
Population 4,689.
Denver 215 miles.

As the branch railroad lines that enter Salida are narrow-gage all the freight originating on them and bound for the East must be reloaded into standard-gage cars. This reloading entails considerable expense and loss of time and is a great handicap to the shippers on the narrow-gage lines. Narrow-gage cars can run, however, between Salida and Leadville, because here a third rail has been maintained for the benefit of the mining interests in shipping ores to the smelter.

A description of the route over Marshall Pass and through the Black Canyon begins on page 158.

MAIN LINE OF RAILROAD FROM SALIDA TO MALTA.

On leaving Salida the railroad runs up the right side of the valley, but it leaves the base of the hills in a short distance and finds a route near the middle of the valley. About a mile out of Salida the traveler has on the west (left) an unobstructed view of the southern part of the Sawatch Range, which at its extreme southern point is crossed by the narrow-gage road over Marshall Pass. This line, after passing westward from Salida about 6 miles, enters the range by Poncha Canyon, which is indicated on Plate XLIV.

SALIDA AND THE VALLEY OF THE ARKANSAS.

From the hill across the river the town of Salida and the neighboring parts of the valley are spread out as on a map. Hunts Peak, marking the north end of the Sangre de Cristo Mountains, is on the left, and Mount Ouray, the south end of the Collegiate Range, is near the middle of the picture. Mount Chipeta shows to the right of Ouray, and Mount Shavano at the extreme right of the picture. The narrow-gage line over Marshall Pass crosses the bridge in the foreground and ascends the canyon in front of Mount Ouray. Photograph by Henry R. Hay, Salida.

80687—22. (Face p. 99.)

The railroad ascends this canyon for several miles and then climbs the mountain slopes on the west, finding a way, after many turns and loops, over the range through Marshall Pass, which lies just beyond Ouray Peak (oo′ray), as shown in Plate LXIX, *B* (p. 162). Although the line up the Arkansas Valley above Salida was completed as far Leadville in 1880 and the line over Marshall Pass in 1881, the latter was regarded as the main line and was the first to be finished through to Salt Lake City.

Near milepost 217 a branch line turns to the left to a large silver-lead smelter in which much of the ore of this region is reduced. A description of such a plant and of the process of smelting is given on pages 252–254. A little farther on there is an abandoned mill on the right of the track, one of the characteristic features of a mining country that has seen its best days. The old mine that supplied ore to be crushed and concentrated in this mill may be seen halfway up the mountain slope on the right. The mill and a single house constitute Belleview, which is merely a siding for trains. A short distance beyond Belleview the railroad crosses the Rainbow Highway, which for some distance beyond this point continues on the right of the track.

From Salida up to the Continental Divide and for some distance down on the western slope the shape of the mountains has been greatly modified by glaciers. There are no glaciers in these mountains now, but long ago, during the great ice age, these ranges, particularly their east sides, were covered by great masses of ice which flowed down toward or into the valleys at their feet, scouring out here and there basins from the solid rock. As most of the striking scenery in this region is due to the effect of these bodies of moving ice they are shown on the accompanying maps as they existed at the time of their greatest development. The effect of high winds, low temperature, and snow on the vegetation at high altitude is also well shown at the summit of the mountains, as exhibited in Plate XLV, *A*, which is a view from the automobile road where it crosses the Sawatch Range west of Salida.

About milepost 220 there are many large boulders, like those at Parkdale, on a low terrace near the river. As the railroad approaches the river the boulders may be seen at close range and at higher levels, until they appear on the terrace above the one on which the railroad is built. These boulders increase in size northward until at a place about a mile from the mouth of Brown Canyon, which is apparently the place from which they were swept, there are boulders of great size; one on the left of the track measures 24 by 14 by 10 feet.

The boulders are distributed in a fan-shaped, delta-like area, showing that on emerging from the canyon the current that transported them swung first to one side and then to the other of this great delta fan and, naturally, as it reached the open country, lost its transporting power and dropped its load. The station of Brown Canyon is at the point where the stream emerges from the canyon which it has cut in the hard granite. (See fig. 20.)

Brown Canyon.

Elevation 7,324 feet.
Denver 222 miles.

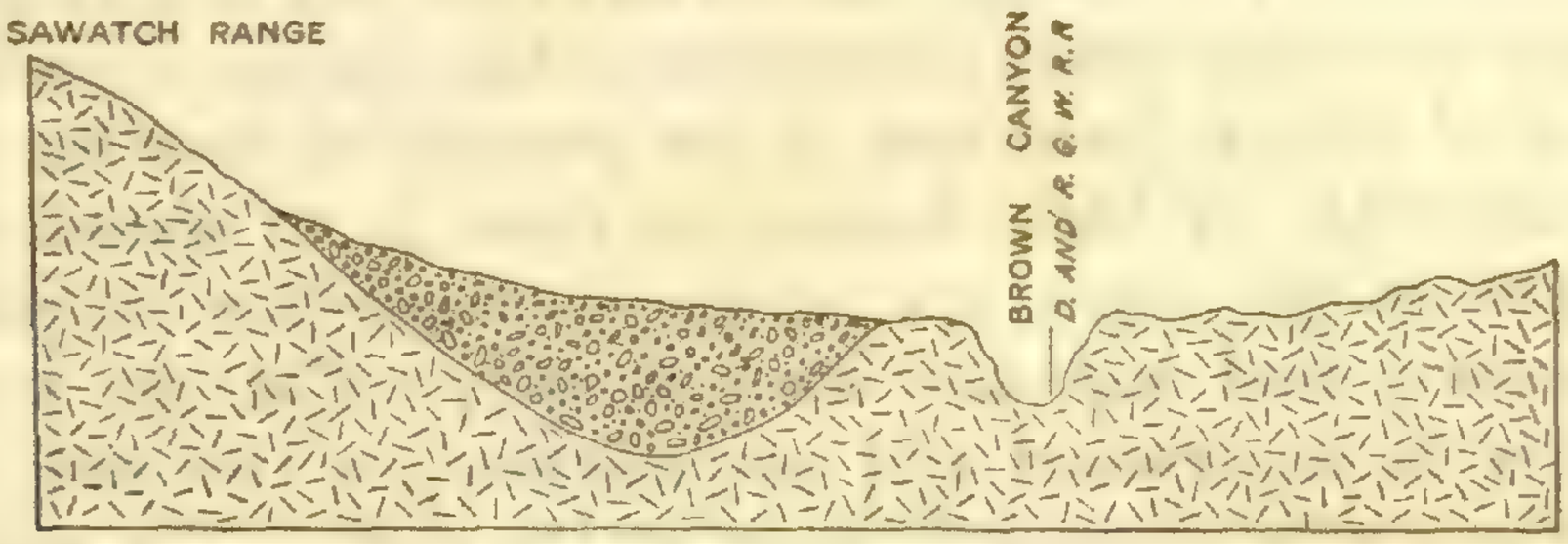

FIGURE 20.—Ideal section from Sawatch Range to Brown Canyon, showing the deep gravel filling in the old channel of the Arkansas.

The canyon is not straight but, as shown in figure 20, winds about in the hard rock, and at one place, half a mile beyond milepost 223, it touches the very edge of the granite mass, so that the recent cutting of the stream has exposed the gravel filling on the west (left; see fig. 21), showing conclusively that when the river established its present course it was flowing on gravel of fairly uniform composition and that the slope of its bed was so slight that it meandered over a broad, flat-bottomed valley in great well-rounded curves. When the uplift came that gave it power to trench its valley, the stream cut directly downward in its established course, and although in some places its course was on granite and in other places on gravel, the river persisted in following that course even to the present day.

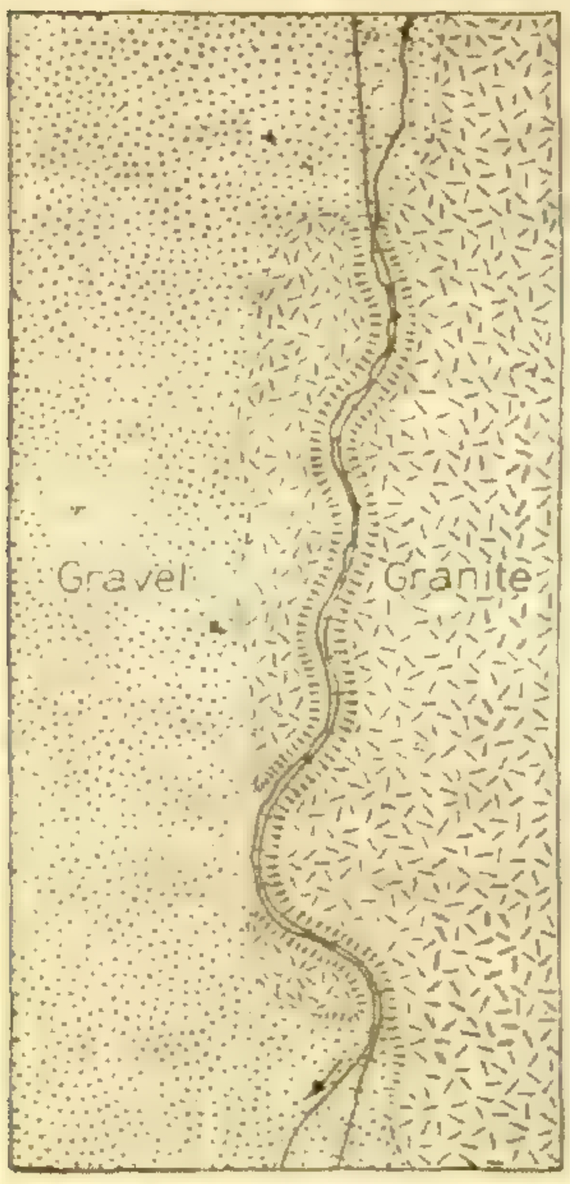

FIGURE 21.—Sketch map of Brown Canyon, showing its relation to the granite and the gravel.

The point of hard rock which the traveler may see on the left before he reaches the rift in the canyon wall is a large dike, which was once molten rock that was forced up from below through some great fissure in the crust of the earth. It is now solidified into a mass more resistant than the surrounding granite, so that it stands up as a nearly vertical wall.

At some places in this canyon there are great granite boulders, around which the water surges furiously when the river is above the

A. SUMMIT OF THE SAWATCH RANGE WEST OF SALIDA.

From the automobile road leading to Gunnison and Montrose the traveler has a good view of the bleak summit of a high range. The trees make a persistent effort to creep up toward the crest, but the strong winds, low temperature, and drifting snow prevent them from reaching the top. As shown in the foreground, many of the trees grow horizontally on the surface, and those that stand upright are severely handled by the snow and wind. Photograph by Henry R. Hay, Salida.

B. CIRQUE ON A MOUNTAIN SIDE.

This picture gives a good idea of the great amphitheaters or cirques scooped out of a mountain side by the old glaciers. The glacier formed at the head of a ravine, and the ice flowed out toward the observer and down the ravine to the left. It cut into the slopes on all sides and in time produced the cirque shown here. Photograph by Henry R. Hay, Salida.

MOUNT PRINCETON.

The towering peaks of the Sawatch or Collegiate Range dominate the upper valley of the Arkansas. This view of Mount Princeton shows the three great spurs on the east side with enormous glacial cirques between them. It was taken from the Trout Creek road and includes the lower end of Buena Vista on the right. Photograph furnished by the Denver & Rio Grande Western Railroad.

normal stage. The traveler may be interested in the circular holes, ranging in diameter from a few inches to many feet, that have been carved in these boulders, and he may wonder how they have been made. Some of these "potholes," as they are called, are shown in Plate XLVII, *B* (p. 98). If he could look down into the potholes he might see the "tools" by which they were carved. These tools are small boulders, which the water, when it is high, whirls round and round in the narrow space. This constant grinding wears the holes deeper and broader and unites many adjacent holes, forming a channel in the rock.

About three-quarters of a mile beyond milepost 224, which is in the narrowest part of the gorge, the railroad crosses a rather large creek that enters the river from the east. A branch road once ran up this stream nearly 6 miles to some iron mines, but the mines were unsuccessful and the line has been discontinued, although it is still shown on some recent maps. The point where this branch joined the main line was known as Hecla Junction. The canyon is near the western edge of the granite area, but the gravel filling on the left can not be seen from the train.

About half a mile beyond milepost 230 the railroad crosses the river and in a short distance emerges from the rocky reaches of Brown Canyon. This canyon is extremely interesting from many points of view. To the geologist it reveals a whole chapter in the history of this region, a chapter that tells of its depression down nearly to sea level, when the highest mountains of Colorado were small ridges only 4,000 or 5,000 feet in height, and then of its elevation to its present position. To the lover of beautiful scenery it affords a pleasing variety of landscape, for one tires of even the finest scenery if it is without variety; but in passing from the open valley above Salida, where the principal objects in sight are the great mountain peaks of the Sawatch Range, to the confining granite walls of Brown Canyon the traveler experiences a pleasing sensation of the nearness of the landscape and of being brought face to face with the works of Nature. To the artist the canyon is beautiful because of its ruggedness and of the many vistas that may be obtained of the stream boiling and foaming through some narrow part, or of some beautiful side ravine where the dull gray of the granite is enlivened by the deep green of the conifers and the soft foliage of the aspens, or, if the season is autumn, by the gleam of gold which the yellow leaves give to the landscape.

The general aspect of the canyon, as well as its relation to the gravel filling on the west, may be seen to excellent advantage by looking back from the train after it has cleared the granite walls and crossed the river to the west side. Here the traveler can see that the higher gravel terrace on the west, as shown in figure 20, is

about level with the tops of the granite walls of the canyon. This fact strongly corroborates the theory that the old valley was filled with gravel that forced the river to the east, onto the granite upland.

Just after emerging from the canyon the traveler may get, on the west (left), a magnificent view of a part of what is frequently called the Collegiate Peaks or the Collegiate Range, from the fact that the three most prominent summits visible from this part of the valley are known as Princeton, Yale, and Harvard.[29] The view on the left also includes Mount Shavano, which is the next high peak south of Mount Princeton. These peaks are peculiarly situated, as they do not form a part of the Continental Divide but stand distinctly east of that crest, and the larger streams heading in the range cut through this outer line of peaks in great canyons that are very

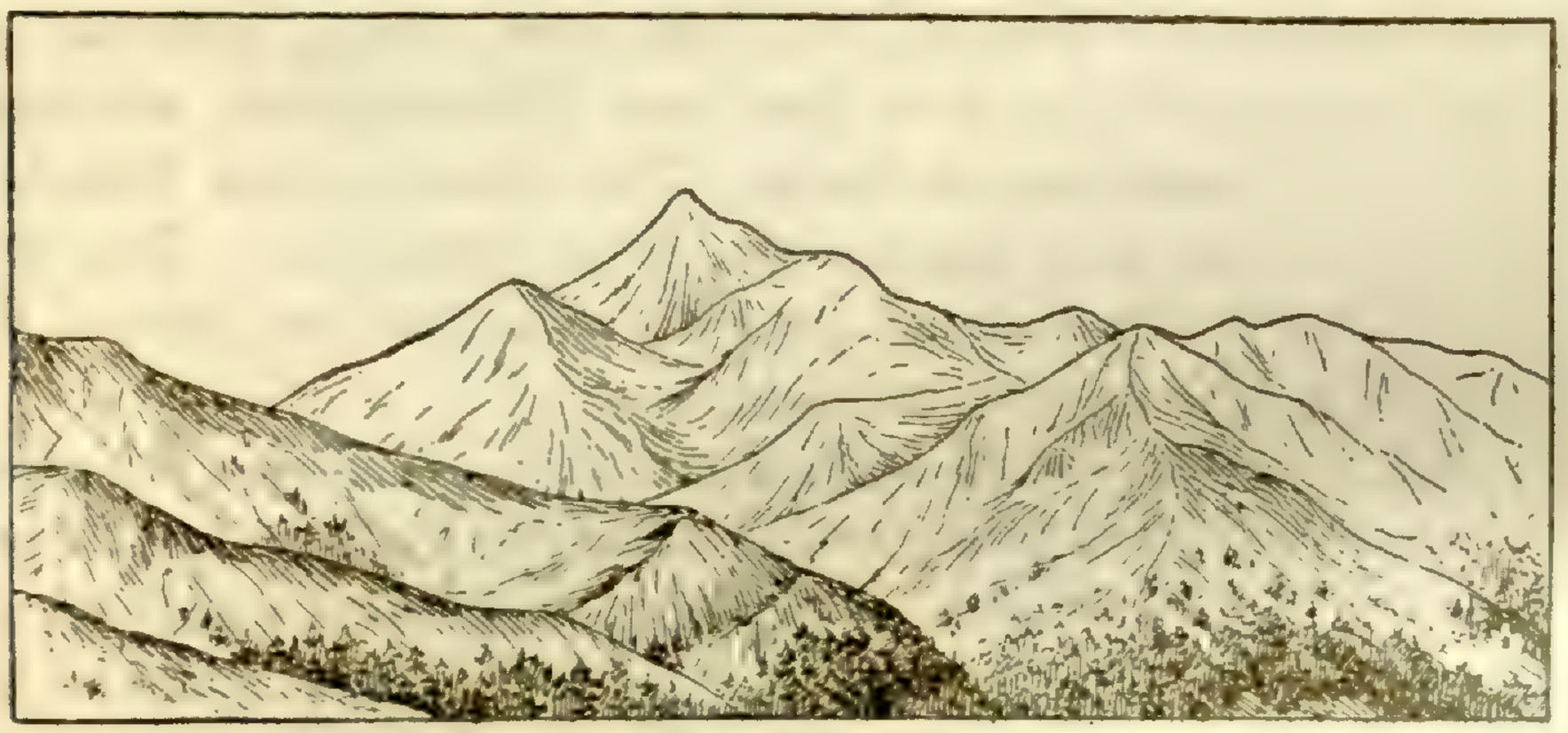

FIGURE 22.—Mount Yale from Nathrop.

striking features. One of the deepest of these cuts, the canyon of Chalk Creek, which the traveler may see on the left, separates Mount Shavano on the south from Mount Princeton on the north. The view of Mount Yale as seen from this point and represented in the sketch (fig. 22) is the best to be obtained from the railroad, for north of this point the big shoulder on the east side

[29] The history of the naming of these peaks is given below in the words of Prof. W. M. Davis, of Harvard University:

In the summer of 1869 Prof. J. D. Whitney visited the Rocky Mountains of Colorado with a small party, including four of his students (Archibald R. Marvine, Henry Gannett, Joseph H. Bridges, and William M. Davis) in the mining school at Harvard. His object was chiefly to determine the altitude of the loftiest ranges that he could reach, regarding which a brief report was published in Petermann's Mitteilungen (1871). The highest summit that he found (14,399 feet), was in the Sawatch Range west of the upper Arkansas Valley and was named Mount Harvard, after the university in which he was then teaching; while the next higher summit immediately to the south in the same range (14,172 feet), was named Mount Yale, after the university from which he graduated 30 years before. The name Mount Princeton was given a few years later to the fine mass (14,177 feet) next south of Mount Yale.

conceals the main sharp peak, and the mountain looks like a great round mass. Mount Harvard lies to the right of Mount Yale, and this mountain, as seen from any point on the line, presents the appearance of a great mass without a definite or sharp top.

Just before reaching Nathrop the railroad crosses Chalk Creek on a high bridge. The traveler may look up into the great canyon which this creek has cut in the Sawatch Range, whose base is only 5 miles away, though the head of the creek is 20 miles farther back. The Colorado & Southern Railway has a narrow-gage road in operation up this creek to the mining region about St. Elmo; it formerly crossed the range to Parlin and Gunnison, on the Marshall Pass branch of the Denver & Rio Grande Western, but the long summit tunnel has caved so badly that traffic beyond Hancock has been abandoned. This road may be seen on the left just after the train passes the village of Nathrop.

The gorge that Chalk Creek has cut through the mountains has been scoured by a great glacier, which has greatly broadened its bottom and smoothed its sides, but unfortunately the railroad is so far from the base of the mountains that the traveler can not see how much the ice modified the shape and appearance of the canyon nor the enormous terminal moraine, a mile long and several hundred feet high, that it built. This moraine lies outside the mountains, but it can not be seen from the train.

The mountains on both sides of Arkansas Valley are included in the Leadville National Forest, in the administration of which the Forest Service has come into close contact and, at first, into conflict with the miners regarding their right to cut timber on the public domain. The manner in which this subject has been handled and an outline of the results obtained are given by Smith Riley, district forester, in the footnote.[30]

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[30] As the train goes up the valley of Arkansas River from Salida to Buena Vista the traveler sees the Collegiate Range on the west and the Trout Creek Hills and Buffalo Peaks on the east. These hills and mountains are all in the Leadville National Forest, which covers an area of 935,566 acres.

The celebrated Leadville and Summit County mining districts of Colorado are almost wholly in the Leadville National Forest. The question at once arises, What effect has the establishment of these national forests had upon the mining industry—are they beneficial or detrimental to it? This question can be best answered by giving a brief sketch of the practices and customs of the mining communities in the State at the time the forests were created as compared with those prevailing at the present time. In the early days, when "mineral" was discovered, it was the practice to stake as claims all the ground that might become affected by the discovery One incentive for this action was the desire to control the timber; another was the desire to control all possible mineral deposits found subsequent to the discovery. No effort was made to conform with the require-

From the village of Nathrop the traveler, on looking back to the east, may obtain a good idea of the kind of country the granite makes somes distance back from the main drainage lines. It forms a plateau or table-land that rises from 1,500 to 2,000 feet above the level of the valley. This plateau is probably a remnant of a once rolling surface that extended over most of the mountain country and that has been described as a peneplain.

Nathrop.

Elevation 7,696 feet.
Population 196.*
Denver 233 miles.

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ments of the law as to what constitutes a claim.

When an application for mineral patent is now received for a piece of land in a national forest the land is examined by an experienced, qualified mining expert of the Forest Service to determine the validity of the claim. If the claim is found to be invalid the evidence of its invalidity is submitted to the General Land Office, where action on the application for patent is taken. Such examinations have done much to stop the exploitation of other than mineral land under the mining laws as well as the wholesale location of timber by an individual or company to the detriment of the lone prospector.

Particular attention is given by the Forest Service to the preservation and protection of timber in regions where it may be needed for prospecting and mining. A prospector can obtain timber to develop his claim from the national forest without charge, but a paying mine must buy its timber. Where forest land in a mining district is sold care is taken to leave on it sufficient timber for its exploitation as mineral land should mineral deposits he found on it.

Roads, trails, and telephone lines are built by the Government through national forests to make them accessible for administration and protection. These conveniences are open to the prospector, who in turn is welcomed by the forest officer because of the assistance he is able to render in reporting fires or the misuse of forest property. Very little of the timber, however, that is used in the tunnels, shafts, and stopes of the Leadville mines has been obtained from the basin of Arkansas River. Practically all of it has been obtained from Fryingpan Creek, in the Sopris National Forest, and from the Eagle River country, in the Holy Cross National Forest. Most of the round timbers that are loaded on freight cars at Mitchell, Pando, or Red Cliff, on the other side of the Continental Divide, are destined for the Leadville mines.

The forests around Leadville are composed almost entirely of lodgepole pine (see Pl. XXXVI, *B*), and the city stands in the upper part of the zone of this tree. The traveler will note the large number of young trees scattered over stump areas or areas in which dead standing trees give evidence of forest fires. Lodgepole pine seeds readily in the soil and ash of fire-swept districts, for the cones that contain the seed may remain on the tree year after year without opening, though the seed continues fertile. In this way large quantities of fertile seed accumulate on the trees, so that when a forest fire occurs the cones are slowly opened by the heat, and the seeds are released and fall in great numbers to the ground to sprout and grow, if the weather is favorable. Where the growth of lodgepole pine after a fire is scattering the fire may have been so severe that it burned up a large number of the cones, or favorable weather

About a mile north of Nathrop the Denver & Rio Grande Western crosses to the east side of Arkansas River, and a short distance farther on it crosses the Colorado & Southern Railway, which follows the east side of the valley from this point up to Buena (bway'na) Vista. After he crosses this railway the traveler, if the light is just right, may see faintly in the distance on the side of Mount Princeton a wagon road that zigzags up the south spur of the mountain to some old mines, from which it has been extended to the top. This road may soon be so improved that automobiles can reach the top of the mountain, from which an even wider view may be obtained than that from Pikes Peak, for Mount Princeton is surrounded by range after range that can be seen only from some commanding eminence. The height of Mount Princeton is 14,177 feet. Its relation to the Arkansas Valley is well shown in Plate XLVI.

Near milepost 237 the Denver & Rio Grande Western Railroad again crosses Arkansas River, and a short distance beyond this crossing the traveler may see Trout Creek Pass on the east (right). The Colorado Midland Railway formerly operated a line through this pass. At a lower level he may see the Colorado & Southern Railway, which crosses through the same pass. This road formerly connected the lines of this system in South Park with the line that runs southward from Buena Vista, but it is not now in operation.

About 2 miles north of the river crossing just mentioned, on the east side of the track, is the State Reformatory, to which juvenile offenders are sent. After crossing Cottonwood Creek, a fine, swift, clear mountain torrent, the railroad reaches Buena Vista ("good view"), a town embowered in a beautiful grove of cottonwood trees and one of the most attractive places in this part of the Arkansas Valley. It stands at the intersection of two of the most noted automobile roads in the State—the Rainbow Highway from Canon City up the Arkansas and the road from Colorado Springs by way of South Park. These roads, after uniting, continue northward through Tennessee Pass and westward to Glenwood Springs and Grand Junction. Cottonwood Creek, which furnishes an abundance of pure water for domestic use and for irrigation, comes down in a deep canyon between Mount Princeton and Mount Yale from the Continental Divide, which is some distance west of these high peaks. Long ago a great glacier occupied the canyon and scoured it out, but it came down only to the point where the canyon opens out into the

Buena Vista.

Elevation 7,968 feet.
Population 903.
Denver 240 miles.

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may not have followed the fire, so that only a very small percentage of the seeds could survive. Where the traveler sees a dense patch of these pine trees in a tract on the mountain side, however, he can be almost certain that a fire has swept over that tract and was followed by a heavy fall of seed and favorable weather during the subsequent growing season.

valley, and the traveler on the railroad has no opportunity of seeing the results of its work.

The attractions of Buena Vista consist of an admirable climate and beautiful surroundings for summer visitors; the ascent of Mount Princeton, which is a little higher than Pikes Peak; and Cottonwood Hot Springs, at the mouth of the canyon 6 miles above Buena Vista. It is proposed to lay a pipe line down to the town and establish bath-houses so that more visitors may be able to bathe in the mineral water. Buena Vista was established in 1879 and is the seat of government of Chaffee County.

Immediately north of the station at Buena Vista the traveler may notice on both sides of the track huge boulders that are arranged in the form of a fan, similar to the great fan of boulders at the mouth of Brown Canyon. The boulders at Buena Vista may not be so large as those at the mouth of Brown Canyon, but many of them measure from 12 to 15 feet in their longest diameters.

Nearly 2 miles from the station the Denver & Rio Grande Western Railroad enters Wildhorse Canyon, a small canyon cut in the massive granite. The automobile road does not follow the river in this part of its course, but keeps to the west (left) on the unconsolidated gravel that fills the old valley. This canyon is not so deep nor so continuous as Brown Canyon, and for some distance in its middle part the granite in the west wall gives place to gravel. At its upper end, on the right (east) side of the track, a great block of granite stands like a sentinel. This block is shown in Plate XLVII, *A*. Here the traveler may look back and see that the gravel terrace on the west side of the river stands at about the same level as the top of the granite wall that bounds the canyon on that side. From this fact it is apparent that at one time the old valley was deeply filled with gravel, which was brought down from the high mountains on the west, and that the stream was crowded eastward upon the rocky slope of the valley. Later, when the stream had removed some of this gravel and resumed the work of cutting its valley down, it again flowed on the hard granite, but far to the east of its former course. However, a stream has no power of itself to alter a course it once establishes, and so Arkansas River persisted and cut the canyon in the hard rock.

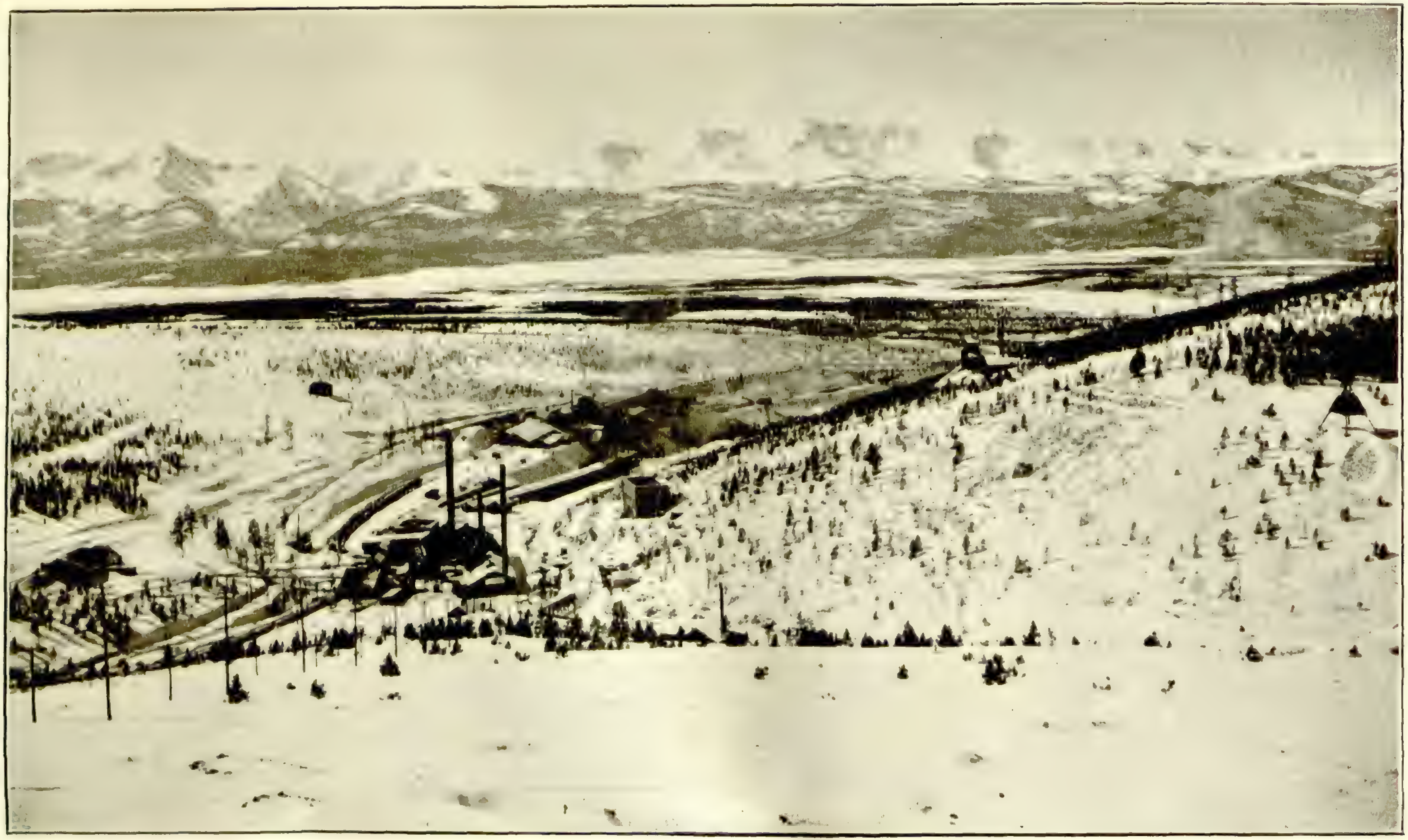
On emerging from Wildhorse Canyon the traveler may obtain a much better view of Mount Yale (14,172 feet) than that which he obtained near Buena Vista. Here it appears as a single peak directly across the valley, with the sharp summit of Mount Princeton on the left and the great rounded mass of Mount Harvard (14,399 feet) on the right. A little farther along he may see a great hollow that apparently has been scooped out of the east slope of Mount Harvard on the side facing Arkansas Valley. This hollow is semicircular in

A. NATURAL GRANITE MONUMENT.

This striking remnant of massive granite at the upper end of Wildhorse Canyon stands to the right of the tracks and is at least 60 feet high. The granite is cut by dikes of other material, which show in the picture. Photograph by Marius R. Campbell.

B. POTHOLES IN GRANITE BOULDERS.

In Brown Canyon there are many large granite boulders around which in ordinary stages the water swirls and boils but which in floods are completely submerged. The rushing current rolls round and round small boulders caught in hollows of the larger blocks, cutting great circular pits called "potholes." Photograph by Marius R. Campbell.



MOUNT ELBERT AND MOUNT MASSIVE.

Colorado's highest peaks as they appear in winter from Leadville. A large smelter in California Gulch is shown in the foreground. The east face of the range is cut by many cirques, from which great glaciers once flowed down into the valley of the Arkansas. Photograph furnished by the Denver & Rio Grande Western Railroad.

outline and has a nearly flat floor. From the train it looks like a very small feature, but its walls are probably several hundred feet high, and it is not less than half a mile across. (See fig. 23.) To such a semicircular hollow as that on Mount Harvard or the one on the Continental Divide west of Salida (Pl. XLV, *B*) geologists have applied the French term "cirque," meaning circle. It was produced by a small glacier that was formed in a ravine far up on the mountain slope.

As far as milepost 246 the valley has a general width of 5 to 8 miles, but on looking ahead the traveler may see that it becomes narrower and finally seems to close in completely. The old and rather broad valley doubtless continued to the head of the stream near Tennessee Pass, but a little distance above Riverside it is so

FIGURE 23.—Great cirque on Mount Harvard.

much filled with gravel and boulders that it is scarcely recognizable. Near this constricted part of the valley large boulders abound, forming a fan similar to the boulder fans observed at the mouths of the canyons below. The change in the character of the valley is due to the fact that in the Great Ice Age, when glaciers were active, they formed mainly on the mountain slopes at or above an altitude of 11,000 feet and flowed down the side canyons or gulches for distances that depended on the grade of the canyon and the size of the glacier. In the Arkansas Valley below Riverside the glaciers that headed in the Sawatch Range reached only to the mouths of the side canyons, but farther north the altitude of the valley is so great that they not only reached the mouths of the rock-bound canyons but pushed out into the river and filled the main valley with the rocky débris that they had carried on their surfaces or that had been embedded in them. This condition prevails above Riverside, and for this reason the valley is much narrower here than it is lower down. The glacial material brought down from the mountains crowded the river to the east side of the valley and even forced it over on the granite of the east wall, as it did in the other canyons below. The large blocks of rock that were derived from this granite were carried down the canyon and for some distance out on the flat valley floor.

Riverside.

Elevation 8,374 feet.
Denver 248 miles.

The canyon which the railroad enters at milepost 252, although short, is rather picturesque and has a steep granite wall on the east side, against which the stream has been crowded by the glacial drift that was brought down Pine Creek from the west. Through this narrow passageway the river boils and surges over and around the great boulders that obstruct its course. The glacial drift is first seen as the railroad bends sharply to the left, a little above milepost 252. At first sight it may not be apparent that this material differs from the gravel that composes the terraces below, but careful inspection will show that the boulders are all composed of fresh rock and that their surfaces are generally smooth and unweathered. It also shows that many of them are scratched, or striated, as the geologist calls it, as they were brought down by the glacier and held like a giant rasp against the rocky sides of the canyon. Such scratches are regarded as reliable indications that the boulders have been transported by ice.

At milepost 254 the railroad crosses the river to the east side and follows the east bank for a long distance. In some places the west wall of this canyon is composed of granite and in others of glacial drift, but the traveler on the railroad train can not determine the reason for the presence of the drift until the train has rounded the broad curve above the bridge and he is able to see on the west (left) up the open valley of Clear Creek. As this view up the creek, which is well worthy of attention, can be had only while the train is running a quarter of a mile the traveler who wishes to see it clearly should be ready to look this way as soon as it becomes visible. By looking up Clear Creek he will see that the stream issues from the high mountains in a canyon that has a broad U-shaped cross section, and that outside the mountains it is walled in by parallel ridges of broken rock and gravel that was deposited or heaped up by the ice. Such ridges along the sides of a valley are called by geologists lateral moraines. The moraine on the north side of Clear Creek. at the point where the stream emerges from the mountains, is 700 feet high, and its front, which is composed of loose material, is as steep as it can stand. The moraines run parallel with the creek until they reach the river, where they curve around and nearly meet, forming a loop that originally inclosed the mass of ice. The glacier not only reached the river, but at times pushed a little farther and heaped up the loose gravel on its east side. Naturally when such a glacier melts away the part of the valley it occupied will be left relatively free from boulders, and it therefore generally forms a swampy tract or a lake surrounded by a ridge or ridges of gravel. The stream quickly cuts a trench in this bounding ridge, so that the valley is thus drained through a narrow cleft. The users of water far down the Arkansas have taken advantage of this natural site

GEOLOGIC AND TOPOGRAPHIC MAP

OF THE

RIO GRANDE ROUTE

From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
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1922

EXPLANATION

		Age	Thickness in feet
A	Mountain glaciers as they were during the Great Ice Age	Pleistocene	
B	Gravel, sand, and clay	Pleistocene and late Tertiary	
J	Dark marine shale (Mancos shale)	Upper Cretaceous	2,500±
M	Brown sandstone (Dakota sandstone)		50±
N	Variegated shale and sandstone (Gunnison formation)	Cretaceous (?) and Jurassic	400±
R	Red sandstone and shale (Maroon formation)	Carboniferous (*Pennsylvanian*)	1,500
S	Red sandstone, conglomerate, and shale (Weber formation)		2,800
U	Blue limestone (Leadville limestone, Ouray limestone)	Carboniferous (*Mississippian*) and Devonian	200
V	Limestone and quartzite: Parting quartzite 40′; White limestone 160′; Lower quartzite (Sawatch quartzite) 175′	Ordovician and Cambrian	375
X	Granite	Pre-Cambrian	
Y	Lava flows	Tertiary	
Z	Intrusives		
	Fault		

for a storage reservoir and have built a dam across the lower end of the valley and thus connected the two parts of the moraine, so that the swampy area has become a reservoir for the storage of water until it is needed in the valley far to the east for the irrigation of crops.

Just above the mouth of Clear Creek the Colorado Midland Railway formerly crossed the Denver & Rio Grande line by an overhead bridge, and a short distance farther on it crossed the river and continued on the west side of the stream nearly to Malta. Just above the crossing the river and railroads enter a granite canyon, which is very narrow but of slight depth, and continue in the canyon to and beyond the village of Granite. (See sheet 4, p. 134.)

Granite.

Elevation 8,943 feet.
Population 79.
Denver 257 miles.

This village has been the center of large gold-dredging operations,[31] but this industry is now a thing of the past, and the village is known principally as the stopping point for those who wish to visit Twin Lakes, a noted local resort, reached by stage from this station. Lakes are not numerous in the mountains of Colorado, so that even small ones such as Twin Lakes are highly prized.

Above Granite the railroad continues in the canyon, but the walls are low and at many places the traveler may catch glimpses of the surrounding country. About 2 miles from Granite he may see on the west (left) and ahead the ridge of gravel which bounded the glacier that once occupied the valley of Lake Creek and which now sur-

[31] In the days of '49 gold was obtained from gravel mainly by the laborious method of panning, or by the use of the cradle, both slow and crude methods that do not appeal to the gold hunter of the present day. The cradle and the pan gave way to hydraulic mining, which was a great improvement on those early methods, as it enabled the operator to handle an enormous quantity of gravel at slight expense, but the waste sand and gravel produced by the process so choked the streams below the operations and so greatly interfered with the growing of crops that laws were passed prohibiting its use.

Now dredging has replaced all other methods of handling placer deposits, for it is the most efficient method yet devised, one that can show a profit even where the gold recovered amounts to only a few cents to the ton of material handled.

Dredging is practicable wherever the placer lies in the bottom of a valley or on a fairly level surface where water is available and where the placer is extensive enough to provide for several years' operations. A large excavation is made in the gravel, and in it a dredge is built very much like the great dredges used in digging the Panama Canal. The excavation is filled with water and the dredge scoops up the gravel with its steel buckets down to bedrock; the gravel, after it is hauled aboard the dredge, is washed for the gold, and then the refuse is dumped back into the hole from which it was taken. This method of handling placer gravel requires considerable capital, but on account of the vast quantity of material handled the returns are frequently large and the operation is very profitable. A view of one of the dredges used in the Rocky Mountains is shown in Plate XLI, *A* (p. 81).

rounds the lakes that fill the depression once occupied by the ice. The gravel brought down by this glacier contains considerable gold, and it has been washed extensively along the river by hydraulic methods and by dredges. The washed gravel now lies in great heaps and ridges that greatly disfigure the landscape.

The railroad emerges from the canyon a short distance beyond milepost 262, and the traveler finds that the valley above this point consists of flat, marshy ground which extends nearly to the head of the stream below Tennessee Pass. This upper part of the valley is probably in the same condition as the lower valley was ages ago, before the stream had cut its present canyon, and at a time when it was flowing at the top of the uppermost terrace that the traveler has seen. At that time the lower part of the valley was filled to a great depth with sand and gravel, and all the former inequalities in the surface were obliterated. The upper valley appears to be in that stage to-day. It has doubtless been filled with sand and gravel brought down from the ranges on either side until almost all the inequalities of the bedrock have been concealed, and on this level floor the stream meanders, not exactly sluggishly, for there is considerable slope to the surface, but the quantity of loose material furnished to the stream is much more than it can carry away, so that it is being continually dropped and thus obstructs the channel of the stream and forces it to shift its course to one less direct. If conditions were changed so that Arkansas River had a sharper descent or a greater volume of water, it would have more cutting power, and it would then soon trench this flat bottom, and the cut edges of the valley filling would stand up as terraces just as the terraces stand above the stream lower down.

On emerging from the canyon the traveler again has an unobstructed view of the mountain range on the west, and its aspect is very different from the view which he had below Riverside. The two most prominent peaks visible from the upper end of the canyon are Mount Elbert, which stands just above the moraines of Lake Creek, and Mount Massive, which stands farther up the range.

The altitude of the valley is so great that few plants except grass can be grown to advantage, but the hay crop is luxuriant, and stock raising is the principal business. As the train departs more and more from the great moraines that bound Lake Creek on both sides the mountain peaks back near the head of the creek come into view. These peaks are more rugged than most of those that have been in sight from the railroad. The accompanying sketch (fig. 24) shows the most prominent peaks that can be seen from milepost 265 by one looking to the southwest. These peaks all appear to the left of Mount Elbert, some of them showing from behind the projecting spurs of that mountain. La Plata Peak (14,332 feet) appears in the center,

and Grizzly Peak (14,020 feet) in the distance, with the great lateral moraine of Twin Lakes in the foreground.

On the east (right) the side of the valley for some distance is very hummocky, and on first sight it seems to be a moraine, but closer study shows that the glaciers which once came down the gulches on

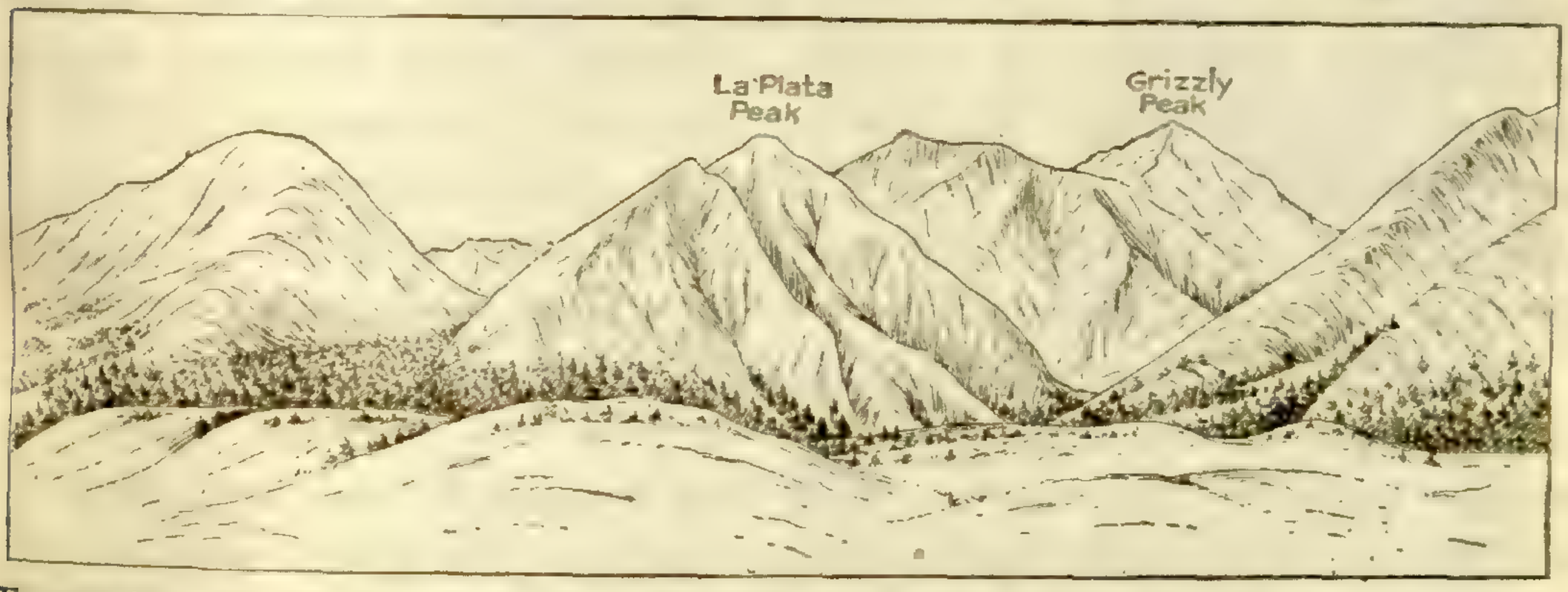

FIGURE 24.—Mountain peaks of Sawatch Range at head of Lake Creek, as seen from milepost 265. Moraines of Lake Creek in foreground.

this side of the main valley did not extend to the area that is within sight of the railroad, and the hummocks are therefore not the result of the action of ice but of landslides and peculiarities of drainage. At milepost 267 Mount Sheridan (13,700 feet) is the most conspicuous feature of the Mosquito Range, on the east (right), but generally the peaks of this range are not so rugged nor so high as those of the Sawatch Range, on the west.

After passing milepost 268 the traveler may see on the east (right), by looking up the gulch past the white wooden schoolhouse, the first indication of the presence of the great mining camp of Leadville—the smoke of the smelters that may be seen over the top of the terrace or the tops of the smokestacks and some of the surface buildings of the mines. No adequate idea, however, of the extent and importance of Leadville can be obtained from the main line of the railroad.

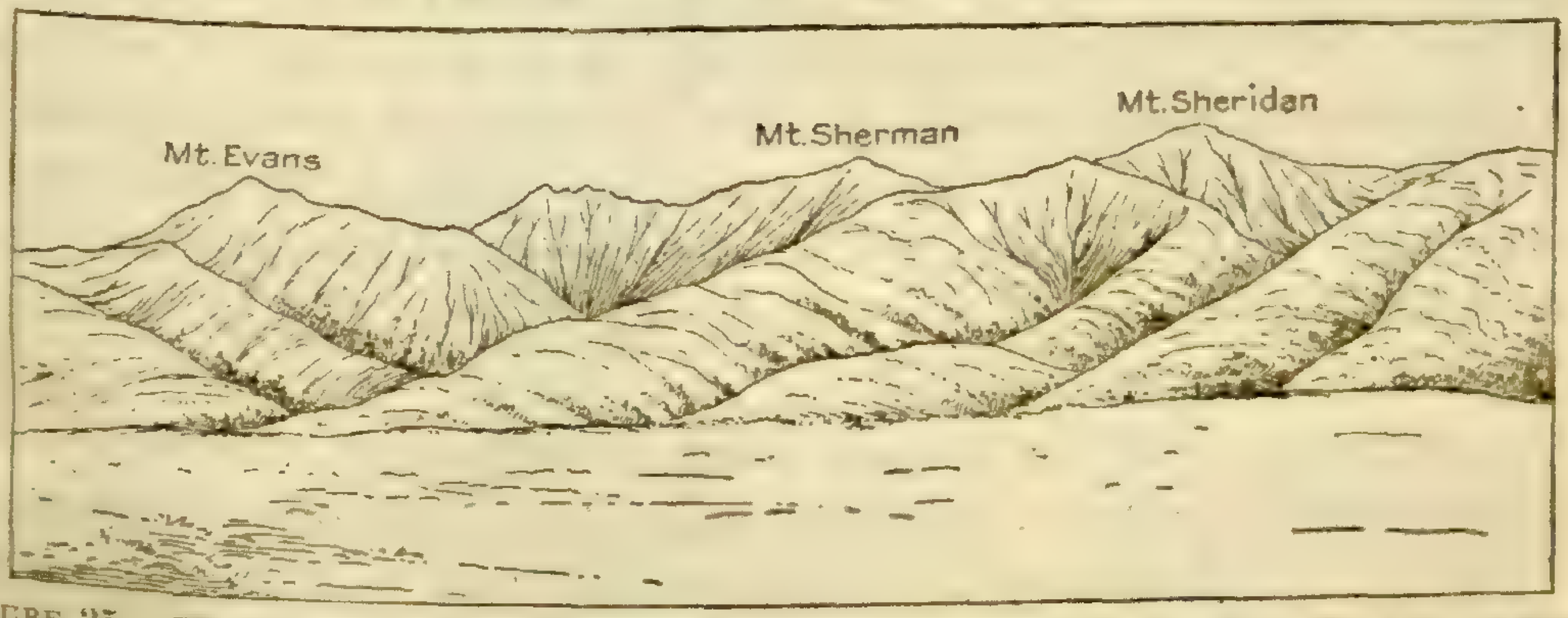

FIGURE 25.—The Mosquito Range as seen from milepost 269, at the mouth of Iowa Gulch.

At milepost 269 a good view can be obtained of the Mosquito Range, known also as the Park Range, on the east. The view from this point is represented in the accompanying sketch (fig. 25),

which shows the relative positions of the different peaks and their names.

The scenery on the other side is dominated by the great bulk of Mount Massive and Mount Elbert. Plate XLVIII shows them as they appear from the vicinity of Leadville. Mount Massive (14,404 feet) is on the right and Mount Elbert (14.420 feet), the highest mountain in Colorado, on the left. Mount Elbert may not appear so high as Pikes Peak, but the traveler must remember that he is looking at Mount Elbert from a much higher position than the one he occupied at Colorado Springs when looking at Pikes Peak, and that the summit of Mount Elbert is only 4,800 feet above him.

Near Malta, the junction point for Leadville, the level marshy valley is more than 2 miles wide. On the east it is bordered by a terrace fully 150 feet high, which was formed by the trenching by the stream of an older flat-bottomed valley. At Malta some of the town of Leadville may be seen. By day the cloud of smoke from its mines and smelters marks the location of the town, and by night the lights of the streets and the smelters may be seen 600 or 700 feet up the slope of the valley on the east (right). As some trains of the main line run by way of Leadville, a brief description of this interesting mining camp will be given. The description of the country along the main line north of Malta begins on page 109.

Malta.
Elevation 9,580 feet.
Denver 271 miles.

LEADVILLE LOOP.

On leaving Malta for Leadville the railroad turns sharply to the east and winds about the gently rolling slopes of the valley side in order to get distance in which to make the ascent without climbing too steep a grade. At first the road winds up the slope among the pine trees, but farther on it comes out upon the edge of a terrace that overlooks a small ravine or "gulch,"[32] as all such features are called in this region, and the traveler may look down upon one of the smelters which is engaged in extracting valuable metal from the ore that is mined in the famous Carbonate Hill, a picture of which is shown in Plate XLIX.

Leadville.
Elevation 10,200 feet.
Population 4,959.
Denver 276 miles.

Leadville is one of the highest towns in the world, standing 10,200 feet, or nearly 2 miles, above sea level. It is also one of the oldest towns of Colorado, dating back to 1860, the year in which the site of Denver was first occupied by white men. In 1859 gold is said to have been discovered in a little gulch that enters the Arkansas Valley from the east at the site of Malta by a party of gold seekers on their way to California, who on that account called it Cali-

[32] This ravine is California Gulch, in which gold was first discovered in this region in 1859.

CARBONATE HILL, LEADVILLE.

Out of the mines on this hill has come some of the richest silver ore ever mined. It made fortunes for the operators in the early days and is yet yielding a large amount of precious metal. Recently the mine dumps have been reworked for zinc ore that was formerly discarded but during the war became very valuable. Mount Elbert in the distance. Photograph by L. C. McClure, Denver.

A. THE PATIENT BURRO.

The humble beast of burden that made possible the development of mines in parts of the West. In derision he has been called the "Rocky Mountain canary."

B. TUNNELS IN EAGLE RIVER CANYON.

View on the eastbound track from a tunnel that pierces a spur of massive granite. The mining town of Gilman, on the rim of the canyon, is shown in the distance. Photograph furnished by the Denver & Rio Grande Western Railroad.

C. EARTH EROSION COLUMNS.

In a semiarid country ordinary earth becomes almost as enduring as solid rock. These columns are 30 feet high and are protected by the caps from rain. Photograph by W. T. Lee.

fornia Gulch. This discovery was made late in the autumn, and the party was not prepared to spend the winter there, so they left; but they returned the next year and established a mining camp which they christened Oro City (meaning Gold City) and which before the end of the year had a population of 5,000. Its fame spread, and in 1861 it was the most populous town in Colorado Territory. In a few years more than $5,000,000 had been washed from its golden sands, but like that of all other placer deposits the life of this one was ephemeral, for in a few years the town was nearly abandoned by the gold seekers, and for several years it played only a small part in the history of the mining region.

From 1874 to 1877 there was a revival of interest in the Leadville region, for silver-lead ores were found at several places in the vicinity of California Gulch, but no development was undertaken until 1878. Before that year the camp consisted of only a cluster of log cabins, but in 1878 a "rush" to the new workings began and the camp at once sprang into prominence as the greatest silver camp in the world. The Denver & Rio Grande Railroad was completed to the gulch in 1880, and the camp soon had a population of 30,000. During the first decade of its existence the silver and lead produced is reported to have been worth more than $120,000,000. Silver mining was the chief industry until the slump in the price of silver in 1893. For a time there was great stagnation, and then the miners turned their attention to the production of gold, silver, copper, lead, and zinc. In 1920 the value of the output of the mines of Lake County, which includes some mines outside the Leadville district, was $4,320,510. The total metallic output up to the end of 1920 is valued at a little more than $419,000,000.[33]

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[33] The following more detailed account of the history of the Leadville district is taken largely from the reports of Emmons and Irving (Geology and mining industry of Leadville, Colo.: U. S. Geol. Survey Mon. 12, 1886; The Downtown district of Leadville, Colo.: U. S. Geol. Survey Bull. 320, 1907).

During the summer of 1859, at the time of the great Pikes Peak excitement, a continuous stream of emigrant wagons stretched across the plains, following Arkansas River up to the base of Pikes Peak. Many of the wagons that had crossed the plains in the early summer, carrying the triumphant device "Pikes Peak or bust," returned later over the same route with the device significantly altered to the single word "Busted," but the more adventurous of these pioneers pushed resolutely up through the narrow rocky gorges toward the sources of the streams. Some wandered across the mountains during the same season into South Park and found gold-bearing gravel on Tarryall Creek and in the neighborhood of Fairplay.

Early in the spring of 1860 some of the prospectors found gold in the gravel at the site of the village of Granite, and others passed on to California Gulch, near the present station of Malta, where the most valuable discovery of the season was made. News

Leadville, like most other mining camps, was built around mills and mine dumps, and much of it is therefore not beautiful.

Any description of mining operations in a mountainous region like that surrounding Leadville, particularly of those of the early

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of the finding of gold in this gulch spread with wonderful rapidity, and eager miners flocked in rapidly.

Large quantities of the precious metal were obtained from the gulch, and within a year the town that was built along its banks, known as Oro City, is said to have had 10,000 inhabitants. Estimates of the gold produced that year differ widely, some being as high as $10,000,000 and others as low as $3,000,000, but the rich placers were soon exhausted, and the population dwindled in three or four years to a few hundred. Some prospecting was done for the veins which supplied the gold of the placers, and several mines that gave a fitful gleam of prosperity to the camp were located, but the general feeling was one of pessimism and the settlement was practically deserted. The rich silver-lead ores, which later were to give this region a world-wide reputation, were undiscovered, or rather unrecognized. The miners had gained most of their experience in the gold fields of California, and to these men silver ore was comparatively unknown and worthless. Few suspected the value of the so-called "heavy rock"—fragments of iron-stained carbonate of lead which obstructed their sluices and had to be thrown out by hand. Although later many claimed to have known of the rich silver-lead ores, their practical discovery was due to A. B. Wood, an experienced miner and metallurgist who came to the region in 1874.

Active prospecting over the entire region may be said to have commenced in the spring of 1877, and the development of rich and productive mines from that time on advanced with a rapidity that was truly marvelous. At the beginning of this era of prosperity the settlement consisted of a few log cabins on the edge of California Gulch, with an estimated population of 200; its business houses consisted of a "ten by twelve" grocery and two small saloons. The three mines were scarcely more than surface scratchings, and a lead furnace was planned but not erected. Communication was had with the outside world by stage or wagon, either across the crests of two high ranges to Denver or by an almost equally difficult road to Colorado Springs. In petitioning for a post office the names Cerusite (the mineralogical name for lead carbonate) and Agassiz were proposed but rejected as being too scientific. Lead City was suggested, but finally a compromise was reached on Leadville.

In 1880, three years later, the city of Leadville had 15,000 inhabitants, 28 miles of streets, and more than 5 miles of water mains and was in part lighted by gas. It had 1,100 pupils in daily attendance at its schools, five churches, three public hospitals, an opera house, six banks, and many business houses, constructed of brick and stone. Its assessable property is estimated to have been $30,000,000, and $1,400,000 was expended in 1880 in new buildings and improvements. To support this population there were over thirty producing mines and ten large smelting works, and the annual production of gold, silver, and lead amounted to $15,000,000.

This burst of development was continued until 1884, but since that year the district has maintained a fair degree of regularity, its average being a little more than $9,000,000 a year.

The value of the total yearly metallic output of the district from 1877 to and including 1917 is shown in figure 26. This diagram shows also the values of the different metals that make up the output. The total production, as shown by the diagram, is

or prospecting stage, would be incomplete without mention of the humble burro (see Pl. L, *A*), that patient beast of burden which has

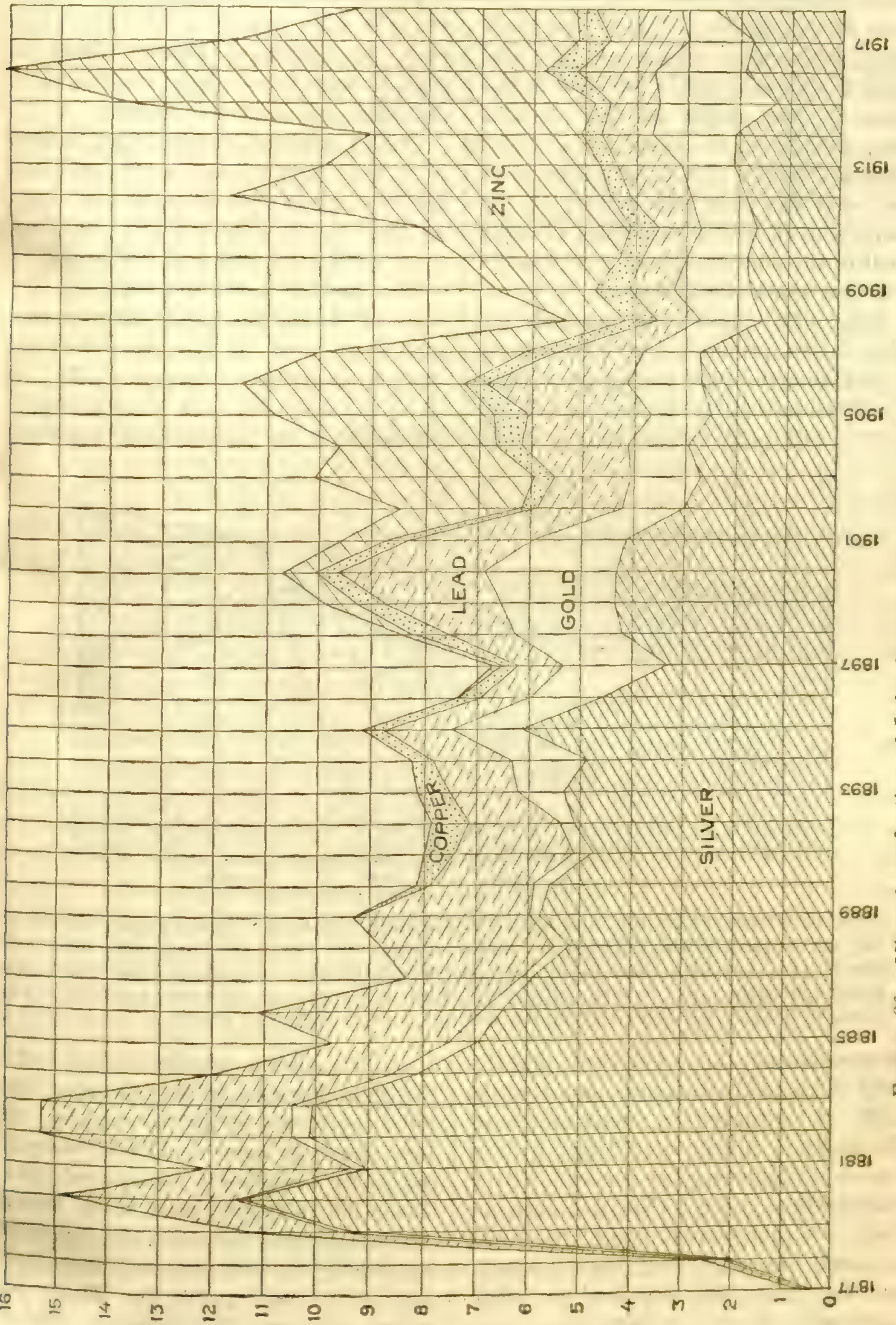

FIGURE 26.—Mineral production of Lake County from 1877 to 1918, inclusive.

fairly regular, except for two marked depressions, one in 1897 and the other in 1908. The first of these depressions was due to a strike, which caused many of the mines to become flooded, and the second to the generally low

been the prospector's constant companion in his lonely wanderings over these bleak ranges and his main dependence for the transporta-

price of the metals. One of the most striking features shown by the diagram is the remarkable increase in the value of the output of this district since 1902, with the exception of 1908, 1909, and 1910. This great increase in the total has been due largely to the marketing of great quantities of zinc. In 1915 the zinc amounted to $8,989,154 out of a total of $13,839,401.

Figure 26 shows the gradual decline in the production of silver from a maximum in 1880 and of lead from a maximum in 1881–82. It also shows that at first gold formed only a small percentage of the whole but that in 1893 it began to increase and that in 1900 it attained a maximum of $2,500,000. Since that time it has run fairly regularly at somewhat over $1,000,000 a year. Copper began to form a notable percentage of the total in 1889, but since that year the output has been very regular, its value amounting to about $500,000 a year. The production of zinc has become one of the spectacular features of the Leadville district. The production of this metal first became noticeable in the returns for 1896, and for a few years it was small. After 1901, however, it increased rapidly until in 1915 it was more than two-thirds of the total output of the district.

Thus Leadville, which began in 1860 as a gold camp, became in 1879 the greatest silver-lead district this country has ever produced and in 1915 became predominantly a zinc district.

The nature and occurrence of the ores of Leadville bear little resemblance to those of the Cripple Creek district, described on pages 47–51. At Cripple Creek the ores were probably deposited from waters that ascended from deep in the interior of the earth through fissures in the breccia that filled the throat of an old volcano. At Leadville the ores replace limestone, but they are closely associated with sheets of porphyry that were forced while molten in between the layers of limestone or between the limestone and adjacent quartzite. This relation is shown in figure 27, which represents a section through some of the workings. Whether or not the ores were brought to this place by waters ascending from great depth or by waters sinking down through cracks

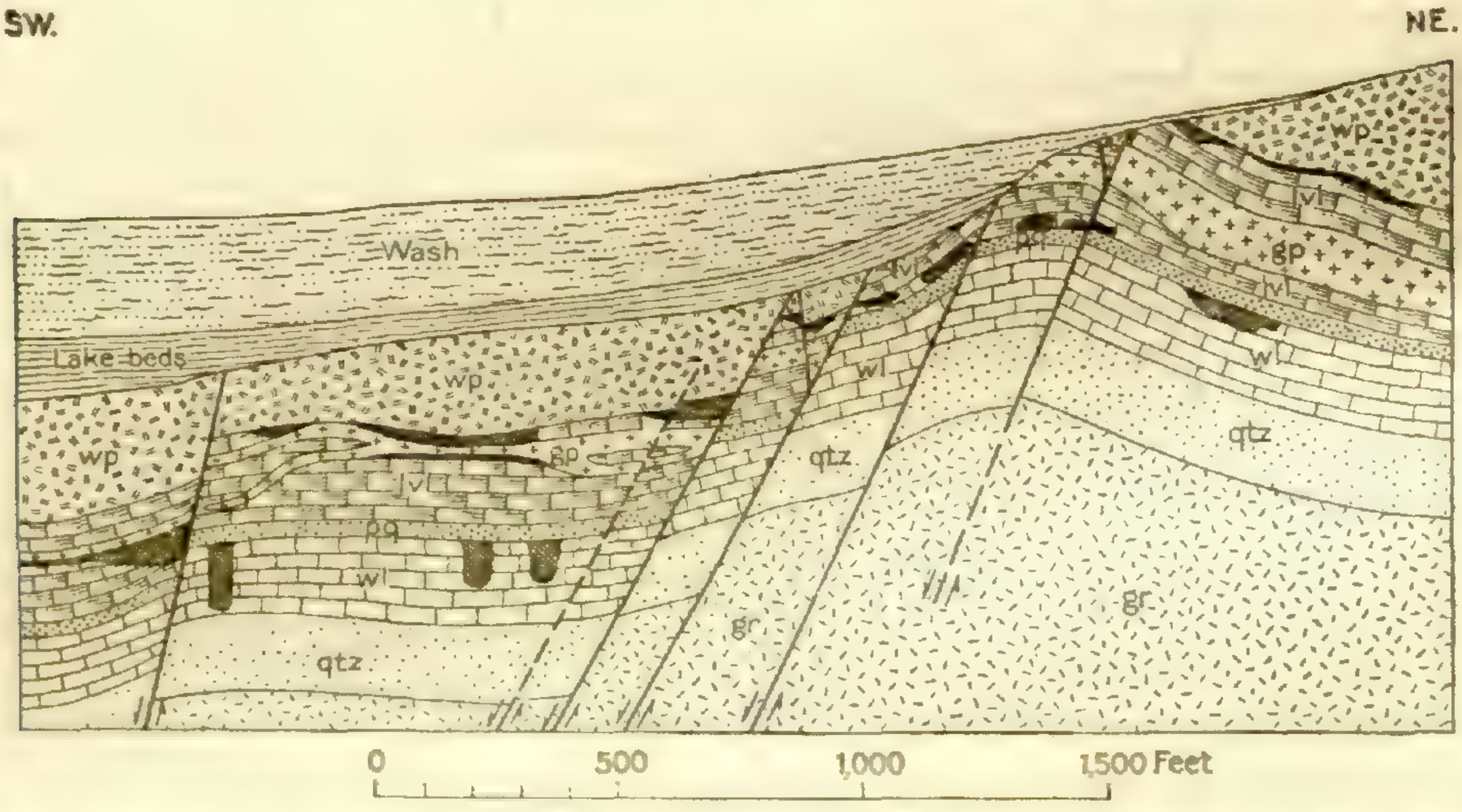

FIGURE 27.—Section through some of the workings at Leadville, showing the relation of the ore to the limestone, porphyry, and quartzite. wp, White porphyry; gp, gray porphyry; lvl, Leadville limestone; pq, parting quartzite; wl, white limestone; qtz, lower quartzite; gr, granite. The ore bodies are indicated by cross hatching. The straight heavy lines represent faults, and the arrows show the direction of movement.

tion of supplies while he has been driving tunnels in search of ore; which has carried lumber and other material for building mine works and even heavy machinery up the steep mountain trails.

MAIN LINE OF RAILROAD FROM MALTA TO GRAND JUNCTION.

Soda Springs and Evergreen Lake, two resorts of local interest, are $2\frac{1}{2}$ miles west of Malta. Evergreen Lake is said to be very attractive, and Soda Springs is much visited by those who hope to be benefited by the use of the waters.

A little north of Malta, at the crossing of a strong stream from the east known as the East Fork of the Arkansas, the north end of the Leadville loop connects with the main line. The East Fork heads in the Mosquito Range, on the Continental Divide, northeast of Leadville. The pass between the head of this stream and Tenmile Creek, the head stream of Blue River, has been named Fremont Pass, on the supposition that Frémont crossed the range at this place in his expedition of 1845, but the "Pathfinder" probably crossed at Tennessee Pass.

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in the rocks from the surface has not ascending from great depth or by waters sinking down through cracks in the rocks from the surface has not been satisfactorily determined, but since the ores were originally deposited they have certainly been concentrated by what is called "enrichment"—that is, by the solution by surface waters of the disseminated ore and its redeposition at a lower level. The ores are generally most abundant beneath the layers or "sills" of porphyry, but they are found also in some places below the quartzite.

The ores originally consisted of sulphides of the principal metals—lead, zinc, copper, iron, and probably silver—but the silver was so much disseminated that it has been difficult to detect. Geologic work in the district has shown that the ores were deposited after the intrusion of the gray porphyry into the limestone and before the rocks were broken by the faults shown in figure 26. After they were deposited in fissures and solution cavities in the limestone much of the overlying mantle of rock was removed, and the ores were brought within the zone of weathering by surface waters. When the sulphides were thus exposed to weathering they were dissolved, changed to carbonates and oxides, and redeposited by the descending surface waters in a rather narrow zone, which has yielded most of the ores mined up to the present time. The extreme richness of the silver ore mined when the camp was at the zenith of its fame was due to the fact that the silver was redeposited near the surface and was the first valuable mineral to be reached in most of the mines. Many of the mines are now working sulphide ores, which are much leaner than the carbonate and oxide ores of the early days. The great increase in the value of the zinc in 1915 was due both to an increase in the production of ore and to a great increase in the price of the metal. This increase in price led to the reworking of dump heaps for the zinc ore that had been thrown away in the earlier and more prodigal exploration of the ore bodies. It is perhaps fortunate that zinc was so nearly worthless in the early days, for that led to its conservation until the World War, when the demand for it was unprecedented.

Long ago, in the Wisconsin stage of the glacial epoch, a great glacier came down East Fork to a point within a mile and a quarter of the Denver & Rio Grande Western Railroad. This great river of ice scoured the valley clean and left it with a broad, flat bottom and a gentle grade. Most of the loose material scoured from the rocky sides of the valley by the moving mass was carried away by Arkansas River, but some was dumped near the lower limit of the ice. Another glacier came down Lake Fork from the high mountains on the west, and this one was so strong that it pushed out across the broad, flat valley of the Arkansas, crowding the stream against the bluffs on the east side. This glacier dumped a great mass of loose material in semicircular form (called a terminal moraine), which the traveler may see on the west (left), but he is so far below its summit that he can not realize its shape. A glance at the map (sheet 4) will show its semicircular shape, which conforms to the curved margin of the tongue of ice that laid it down.

About halfway between mileposts 274 and 275, a mile beyond the crossing of East Fork, the railroad is crossed by a high-tension electric transmission line, which is carried on steel towers. This line carries the power generated in a hydroelectric plant on Colorado River,[33a] which the traveler will see at Shoshone, 10 miles east of Glenwood Springs. As the transmission line for such a plant is very expensive, it follows as straight a course as possible without regard to mountains or canyons. For this reason it does not follow the Denver & Rio Grande Western Railroad eastward from Shoshone but turns to the south and passes up Roaring Fork and Fryingpan Creek to Hagermann Pass. From this point it descends Lake Fork and crosses the Denver & Rio Grande Western, as noted above, and thence goes to Leadville, where much of the power is utilized in the mines and mills. The line then turns northeastward toward Denver and crosses Fremont Pass to Tenmile Creek, which it follows to Dillon. From Dillon it runs due east and crosses the Continental Divide for the third time at Argentine Pass. It then descends Clear Creek, serving Idaho Springs, Central City, Blackhawk, and finally Denver. The traveler who visited Mount McClellan while at Denver probably noted the steel towers and the wide swath cleared of timber for this line along the mountain slopes.

Near milepost 275 Arkansas Valley regains its normal width of about 2 miles. The constrictions lower down are due entirely to the moraines of the glaciers that flowed down from the mountain valleys on the west. Another glacier from the west filled the valley above milepost 278 with a great moraine, which also crowded the stream

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[33a] The name of Grand River, in Colorado and Utah, has recently been changed to Colorado River by act of Congress.

against the east bank. As the roadbed is cut in the hillside it exposes some quartzites and limestones, the beds of which are parallel with the railroad and dip to the east. These beds probably rest on the granite that forms the foundation of the earth's crust in this part of the country, and they are visible for some distance along the railroad track. On the south side of Tennessee Pass, however, the beds are so poorly exposed that the traveler on a passing train can get only momentary glimpses of them.

At milepost 281 the slopes of the valley are gentle, and it seems but a little way to the Continental Divide. When the narrow-gage railroad was first built it climbed over the summit of Tennessee Pass, but now it saves about 250 vertical feet of this climb by a tunnel 2,572 feet long. The station of Tennessee Pass is at the south end of this tunnel. After running a short distance into the tunnel the engine ceases to labor and finishes the long steady climb from Pueblo. So far as the railroad can carry him toward it the traveler has now attained the crest of the continent.

Tennessee Pass.

Elevation 10,240 feet.
Denver 281 miles.

The heaviest grade on the main line on the east side of the Continental Divide is 1.42 per cent, or 75 feet to the mile. This grade extends with few interruptions from Buena Vista to Tennessee Pass, a distance of 41 miles. The heaviest grade on the west side is 3.3 per cent on the westbound track. This grade is maintained for a short distance above Minturn, but throughout most of the distance from Minturn to the summit the maximum grade is 3 per cent, or 158 feet to the mile.

After emerging from the tunnel the traveler may look back and see the apparently low summit of Tennessee Pass. If it were not at the backbone of the continent and the parting of the waters of the Atlantic and Pacific it would not attract attention, for it is only a low, flat cross ridge against which the streams head that flow in opposite directions to the two oceans. The Arkansas drainage has become familiar to the traveler, and now the drainage of Eagle River and Colorado River will become equally familiar as the train descends these streams on its way to the western border of the State. Some travelers may find the Continental Divide disappointing, for they may have pictured it as the sharp summit of a single mountain ridge; but the Rocky Mountains form a great system of interlocking and parallel ranges, only a few of which have sharp, narrow crests, most of them having rounded summits that are not particularly imposing.

North of the tunnel the railroad is at the headwaters of Piney Creek, down which it winds and twists to maintain an easy grade to the main stream, which heads on the flanks of Homestake Peak, on the west. This valley is generally covered with forest except

near the railroad, where the trees have been cut for use in building the railroad and in working the mines. It is now a part of the Holy Cross National Forest, which is described by Smith Riley in the footnote.[34]

Like most mountain valleys that stand at a high altitude the valley of Piney Creek is broad and has gentle slopes. The old roadbed of the narrow-gage line, which crossed the summit of the pass, may be seen on the left of the present road, several hundred feet above it. The old line made a great detour to the west into the main valley, and its bed joins that of the present line at the station of Mitchell. Few rocks can be seen in place, but the tunnel at the pass was driven in granite, which is exposed also from place to place in cuts on the railroad. Just below Mitchell the stream has cut a rugged trench in the granite on the east side of its valley, upon which it had been crowded by a great mass of boulders and clay pushed out by a glacier that came down from the west. This glacier came at least as far as the creek, and at times the ice probably turned northward and followed the creek for several hundred yards. The conditions here resembled those that prevailed in Wildhorse Canyon, already described.

Mitchell.

Elevation 9,925 feet.
Population 55.*
Denver 284 miles.

Below this point the stream has cut a deep gorge in its rocky floor, and its descent is so rapid that the railroad can not follow it, but climbs down more gradually along the west wall of the canyon. The

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[34] After passing through the tunnel at Tennessee Pass the traveler enters the Holy Cross National Forest. This forest, which covers 577,634 acres and includes part of the drainage basin of Eagle River, takes its name from the famous Mount of the Holy Cross, which lies within sight of the railroad but some distance to the west.

West of Minturn the boundary of the forest follows the lower line of timber growth back some distance from Eagle River valley. The mining camps of Redcliff and Gilman are furnished with timber from the dead trees on the large tracts that were swept by fires before the national forest was created. Some dimension lumber is cut from the green Englemann spruce in the vicinity of Redcliff, but most of it is shipped to the mines at Leadville and in the surrounding country, and some is shipped westward and made into crates for the fruit that is raised in the vicinity of Grand Junction.

The trout fishing in the waters of the Holy Cross Forest is excellent, and the Bureau of Fisheries and the Forest Service keep the streams and lakes well stocked by yearly "plants" of young fish. (See Pl. LI, *B*.) Game animals and birds of all kinds are considered a big asset to the national forest, and efforts are made to protect and develop them, but predatory animals are eagerly hunted and destroyed. During the winter, when the weather is severe and food is scarce, the wild animals are closely watched by the forest officers, and if found suffering for want of food the State game authorities are informed and steps are taken to feed them. Wild deer and mountain sheep (see Pl. LVII, *A*, p. 132) feed each winter in Glenwood

A. WILD ANIMALS IN A NATIONAL FOREST.

The United States Forest Service is making vigorous efforts to restock the national forests with wild animals. This picture shows a herd of elk recently shipped from Wyoming and turned loose in the Holy Cross National Forest. Photograph by the U. S. Forest Service.

B. STOCKING A STREAM WITH FISH IN A NATIONAL FOREST.

The streams in the Holy Cross National Forest are stocked with trout fry so that anglers who visit this region will be rewarded for casting a fly. Photograph by the U. S. Forest Service.

old narrow-gage track swung to the east, making a broad loop up the East Fork of Eagle River, and then went northward to Pando, on the level floor of the old lake basin, now called Eagle Park. This grade is now utilized by the automobile road that in a general way parallels the Denver & Rio Grande Western Railroad from Leadville to Grand Junction.

In the vicinity of Eagle Park the granite is overlain by sedimentary bedded rocks that were laid down countless ages ago as sand on the shore of a sea. Since that time they have been crushed in the movements in the crust of the earth that have raised up the mountains. They have been permeated by waters bearing silica in solution until all the pores of the sandstone have been filled with silica or quartz (quartz is a form of silica) and the rock has become a glassy white quartzite. This rock crops out nearly parallel with the railroad and dips from 10° to 20° E. It may be seen in the mountain side on the left nearly 400 feet above the railroad, and its nearly horizontal beds are on the opposite side of the valley about 150 feet above the creek. This mountain side is really the eastern slope of the great Sawatch uplift, or, as it is frequently called, the Holy Cross Mountains, which lie west of the railroad. The mountain slope on the other side

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Canyon, and it is no uncommon sight to see large herds of these animals near the railroad.

Before the white man came to the mountains of the West game animals of every kind were abundant in them. Now, even in the national forests, which are their natural habitat, there are many areas in which they can not be found. In many of these areas, however, wild animals of many kinds could no doubt be propagated and made a source of revenue. The Forest Service is restocking such areas by shipping game animals to Colorado. In shipping these animals care is taken to send them to areas that afford both summer and winter pasturage. The settlement of the valley lands of the State has cut off wild animals from the valleys, where there is only a light fall of snow during the winter, and has limited their range to the higher country. The larger game animals of this country, however, must have winter feeding grounds where the snow is comparatively light. Even the mountain sheep, which during the summer inhabit exposed regions near timber line, migrate in winter to areas that have exposures to the south and west, where the sun and wind keep the grass free from snow.

Plate LI, *A*, shows a number of elk, part of a herd of several hundred that were shipped to Colorado by the Forest Service and turned loose in the mountain region. Recent reports show that these animals are contented and are increasing rapidly.

When the State law was passed prohibiting the killing of elk several herds of native elk still remained in the mountains. There are 2,000 or more in the White River National Forest north of Glenwood Springs, 50 on Williams River in the Leadville National Forest, 250 on the south fork of the Rio Grande in the Rio Grande National Forest, 200 in the Gunnison National Forest, and 80 in the Durango National Forest. Mountain sheep are plentiful near timber line and black-tailed deer throughout the mountains. Having so large a stock of wild animals to start with, Colorado can again become one of the foremost "big game" States of the West.

of the valley is composed mainly of rocks that overlie the quartzite, and if a trench were cut from the top to the bottom of the slope the rocks would appear as shown in figure 28.

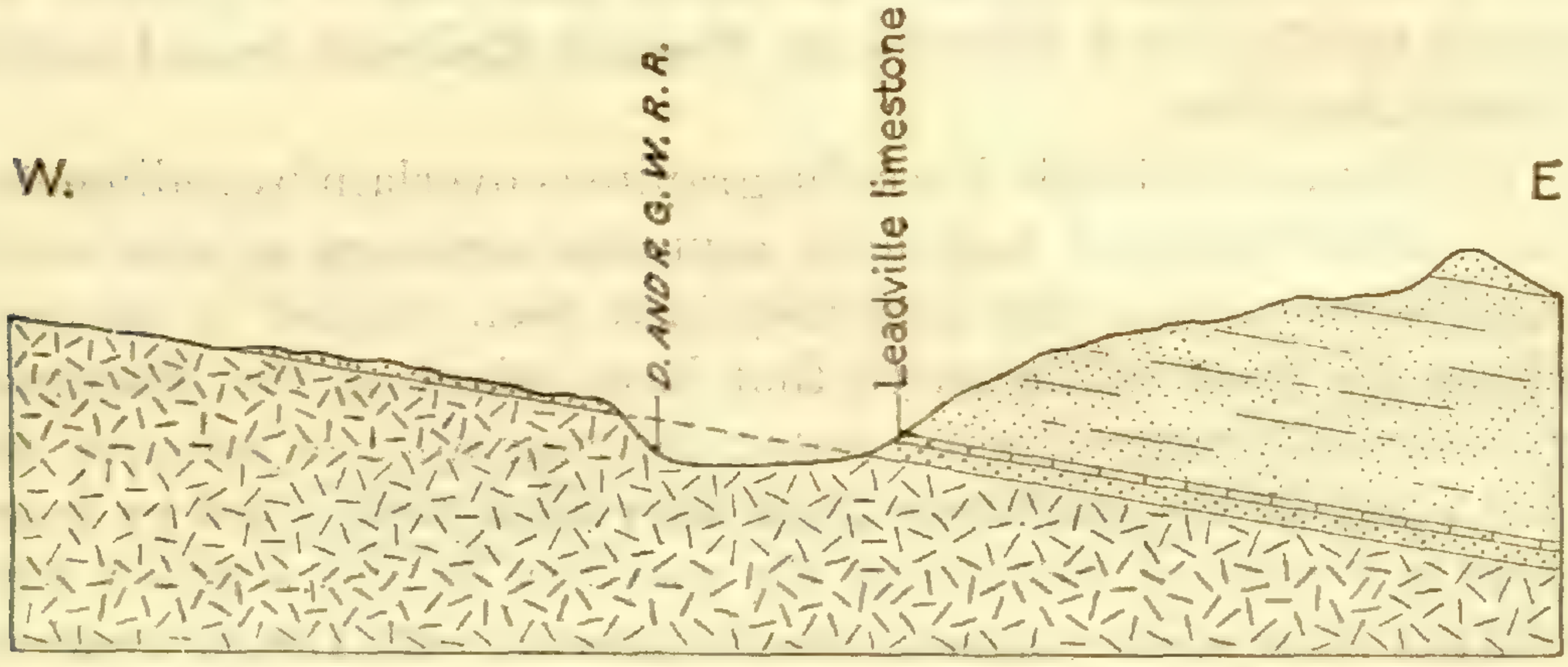

FIGURE 28.—Section across Eagle Park, showing the thin cap of quartzite on the west (left) and the same bed dipping into the base of the slope on the opposite side. The beds dip eastward, away from the Sawatch or Holy Cross anticline.

Near milepost 286 the traveler has an unobstructed view to the east (right) up the valley of the East Fork of Eagle River almost into Fremont Pass. The width of this valley suggests that it has been occupied by a great river of ice that originated in the high summits of the Mosquito Range north of Leadville and flowed down Eagle River valley to a point where the melting exceeded the supply of ice from above, but the region has not been examined carefully enough to determine this point.

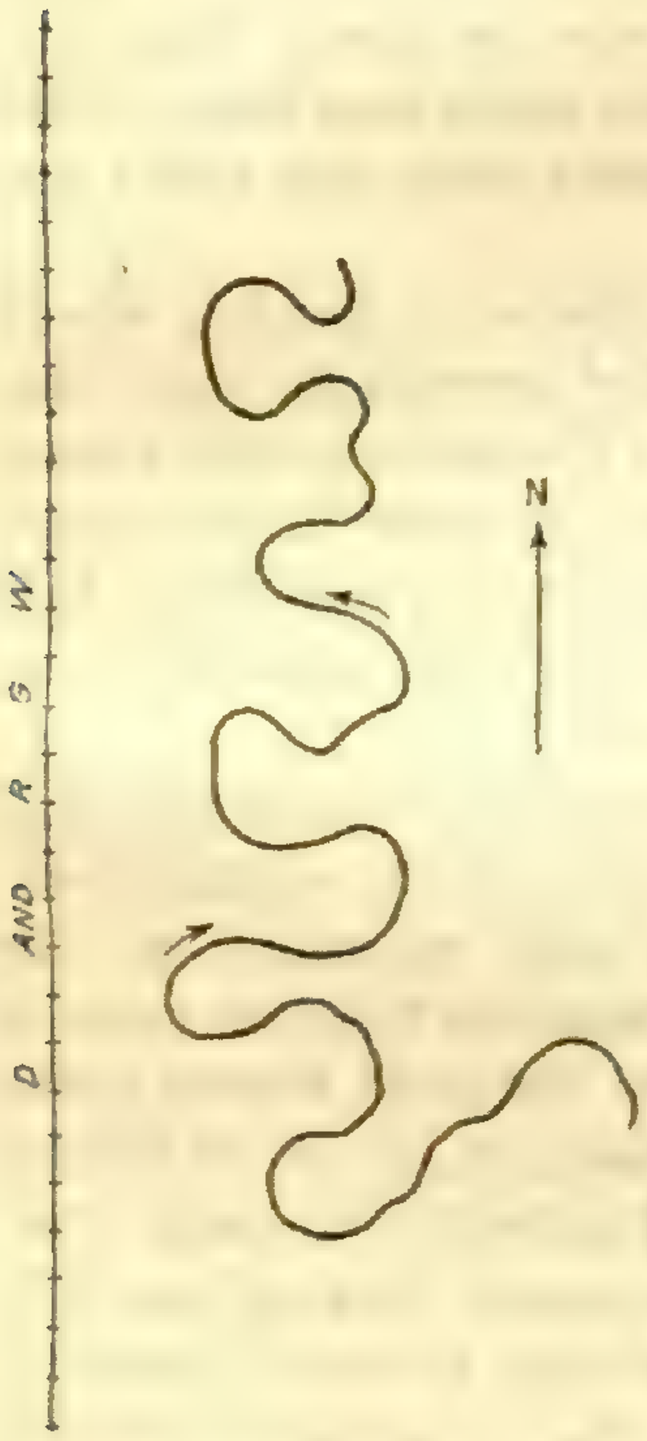

FIGURE 29.—Meanders of Eagle River in Eagle Park near Deen.

In descending the west wall of the valley the traveler may look down upon the level surface of Eagle Park, and one of the features that may attract his attention is the crooked course of Eagle River, which wends its way down the valley in many bends or meanders. These bends, as seen from a point midway between mileposts 286 and 287, are shown in the accompanying sketch (fig. 29). Courses so crooked are not limited to streams in mountain regions but are characteristic of streams that flow on flat surfaces with a grade insufficient to enable them to straighten their channels. The cause of the flat surface here was a dam formed by a glacier in the valley at Pando. In the pond above this dam mud accumulated, and when the ice disappeared the valley was left with a flat mud bottom, which has since been covered with a thick layer of turf.

A little below this point, at the signal tower of Deen, is the beginning of the double track that extends from that place through Eagle Canyon to Minturn.

The railroad follows the outcrop of the bedded rocks, which maintains, at least as far as Pando, about the same relative position as when first seen—that is, about 500 feet above the valley floor on the west and 100 to 150 feet on the east. Just after passing milepost 288, half a mile above Pando, the traveler may see on the east (right) a low ridge of gravel, which extends across the valley and which is thought by some geologists to have constituted the terminal moraine of a very old glacier that once came down Homestake Valley from the southwest, though the writer thinks that it was more probably the terminal moraine of a great glacier that came down to this point from Fremont Pass; but, as already stated, the region has not been examined with sufficient care to justify a definite statement on this subject. The trench that the stream has cut in the moraine has been filled by an artificial dam, and the pond above the dam is utilized for making ice.

Pando.

Elevation 9,209 feet.
Denver 289 miles.

At Pando the railroad turns abruptly to the right and follows the river across the broad valley to its eastern wall. The reason for this abrupt change in the course of the railroad from one side of the valley to the other is that half a mile below Pando the valley, although broad, is almost completely blocked by a great mass of gravel and boulders, which was brought down by a glacier that once descended Homestake Creek, on the west, but pushed a tongue of ice into this valley. (See Pl. LII.) The material brought in by this glacier obstructed the drainage of the valley so much that the river was forced against the east side, and the railroad has followed the pathway kept open by the stream. The course of Eagle River has been greatly affected by this glacier and by the morainic material which it deposited.[35]

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[35] A critical observer will see clearly that Eagle River did not originally find its outlet down its present canyon below Pando, which is too narrow for a stream of its volume, but that it once flowed westward across the low divide to Homestake Creek. (See Pl. LII.) In other words, Eagle River here once turned to the west (left) and flowed northward down what is now the lower course of Homestake Creek. The interesting question then arises, What could have happened to cause a stream like Eagle River, firmly intrenched in a deep valley, to change its course and carve for itself a new valley? Manifestly a stream can not make such a change unless it is compelled to do so by some obstruction. What could have been the obstruction? As there is conclusive evidence that the valley of Homestake Creek was once occupied by a great glacier it seems obvious that ice was the barrier which prevented Eagle River from pursuing its original course and forced it to seek a new outlet toward the north. The conditions as they were

As the railroad curves about the terminal moraine that marks the lower limit of the glacier the traveler may catch, far to the west (left), a fleeting glimpse of the Mount of the Holy Cross (13,986 feet), so named because the snow on its east slope clings throughout the summer in a great vertical cleft that extends nearly the whole height of the mountain and in a horizontal cleft that crosses the vertical cleft, the two together having the form of a cross. The Mount of the Holy Cross is familiar to many persons through Moran's painting, which has been reproduced extensively in colored prints and postcards. It is doubtful whether from Pando the traveler can see, even in the best weather, more than the crest of the peak, but farther along the road, near Minturn, he may obtain a somewhat better view of this well-known mountain. The cross and the mountain that bears it are well shown in Plate LIII.

In some places the rock beds are bent upward and the underlying granite appears in great irregular masses, but beyond such bosses, which continue only for short distances, the quartzite takes its accustomed place at railroad level.

The course of the river is nearly due north to the junction with Weary Man's Creek, which comes in from the east. The combined stream turns abruptly and flows west until it joins Homestake Creek and is again in its rightful valley. At the sharp turn from north to west is situated the mining camp of Redcliff, which is also the county seat of Eagle County. This valley was the route of an exploring party under the command of Capt. (afterward Gen.) John C. Frémont, and a flag on a rocky eminence on the right of the railroad in Redcliff is said to mark the site of an engagement with the Ute Indians in one of his expeditions between 1842 and 1845.

Redcliff.

Elevation 8,608 feet.
Population 347.
Denver 294 miles.

Several mines are in operation in the vicinity of Redcliff, and others may be seen in the canyon between Redcliff and Minturn. (See Pls. L, *B*, and LIV.) Some of these mines have found gold in the granite near the railroad track, but most of them are operating in the Leadville limestone at the top of the canyon wall and the

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at that time are shown on the accompanying map (Pl. LII).

The contrast of the broad valley above Pando and the narrow rocky gorge into which the stream plunges near milepost 290 is striking. To add to the ruggedness of the scene the quartzite, which up to this point has been high up on the slopes, especially on the west side of the valley, is here at creek level on the right; and at milepost 290 the base of the quartzite crosses the stream and makes cliffs on both sides of the gorge. The gorge is so narrow that it can accommodate only the stream and the railroad, but even in order to build the railroad much rock cutting was necessary.

MAP OF HOMESTAKE GLACIER, COLORADO

Showing how it dammed Eagle River and forced that stream to follow a new course below Pando

Scale 1/12000

1 ½ 0 1 2 3 4 Miles

Contour interval 50 and 100 feet.

MOUNT OF THE HOLY CROSS.

This wonderful peak, hidden away in the mountain fastnesses, far from the ordinary routes of travel, bears a shining symbol of the Christian religion. The snowy cross is so protected by clefts in the rock that it never disappears, no matter how long and how hot the summer may be. Photograph by W. H. Jackson.

MINES IN EAGLE RIVER CANYON.

The walls of Eagle River canyon are pitted with mines and prospects—gold in the granite near the river and silver, lead, and zinc in the limestones at the top of the cliffs. The mining town of Gilman, on the rim of the canyon, shows in the distance. The ledges in the canyon wall are quartzite. Photograph furnished by the Denver & Rio Grande Western Railroad.

products are silver, lead, and zinc. At the station at Redcliff the granite may be seen on the right, and above the granite towers a great cliff of quartzite, making an imposing entrance to Eagle River canyon, which begins at this point and extends down the stream for a distance of 4 miles. Overlying the quartzite, but hardly visible from the station, is the outcrop of Leadville limestone, marked everywhere by mines and prospect pits. Above the limestone may be seen here and there ledges of red rock belonging to the upper part of the Carboniferous—the same formation that is so conspicuous about Howard and Salida.

After leaving the station at Redcliff the traveler has just about time to turn in his seat and see the mouth of Homestake Creek on the south (left). Eagle River once occupied this valley, as already explained, but was turned out of its course by the glacier that came down the creek valley from the high mountains on the south. The glacier did not quite reach the site of the railway below Redcliff, but at the time of its greatest extension its front was only a few hundred yards away. Below the mouth of this creek the railroad follows the river through Eagle River canyon, which is not so deep as many gorges cut by Arkansas River on the other side of the Continental Divide, though for narrowness and picturesqueness it is excelled by few.

The stream, which has here become a river, tumbles down through the narrow gorge, dashing its spray over the great boulders that obstruct its pathway. The walls of the canyon rise in jagged pinnacles to a height of 400 or 500 feet and on the east are capped by banded quartzite, the projecting points of which look like ruined castles perched on the rocky walls. Mining has been carried on in this canyon and on the surrounding mountain slopes for many years, and the walls are honeycombed with old prospects and tunnels driven in search of gold. The ores obtained in the limestone above the canyon were lowered to the railroad on inclined tramways or aerial cable lines, the remains of which may be seen along the east wall at points where an unobstructed passageway could be obtained from the head-house, which seems to have a precarious footing on the rocky slope, down to the railroad. For some distance all the mines seem to have been abandoned, but near milepost 296 the river swings to the east and the sedimentary rocks, which dip in that direction, are much lower than they are farther up the stream. Here there are several large mines (see Pl. L, *B*, p. 105), and the mining town of Gilman has been built on a rocky point that projects into the canyon from the east at a height of several hundred feet above railroad level. The mines are in the Leadville limestone, which lies above the precipitous walls of quartzite and granite, and the traveler

may be able to see some of the ore being lowered to a mill in the bottom of the canyon.[36] The ore is crushed in this mill and partly separated from the rock with which it is associated and is then shipped to some smelter for reduction to the metallic state. At Belden the quartzite is about 100 feet above the railroad and has a thickness of 250 to 300 feet. It is overlain by the Leadville limestone, which shows at the top of the canyon wall.

Belden.
Elevation 8,304 feet.
Population 211.*
Denver 296 miles.

Eagle River canyon is so narrow that in building the second track the Denver & Rio Grande was forced to use both sides of the river and even there had to tunnel through many of the projecting points of rock. (See Pls. L, *B*, and LV, *B*.) The westbound track follows the east side of the canyon and the eastbound track the opposite side.

For a short distance below Belden the canyon continues narrow and rugged, but its course is more and more toward the east, and the

[36] A. H. Means in Economic Geology, vol. 10, p. 4, 1915, gives the following section of the rocks in the Eagle River canyon:

Section of rocks exposed in Eagle River canyon, Colo.

Age.	Character.	Formation.	Thickness.
			Feet.
Carboniferous:			
Pennsylvanian	Sandstone	Maroon formation	1,900
	Sandstone	Weber sandstone	3,950
	Shale	Weber shale	50
	Porphyry (intrusive)		100
Mississippian	Limestone, gray and white	Leadville limestone	150
Cambrian	Quartzite	Sawatch quartzite	270
	Granite		

Regarding the ores and the mines Mr. Means says:

"The ore deposits of the district are confined to a relatively small area, the largest part of which lies in the canyon of Eagle River between Redcliff and Gilman, a distance of about 3½ miles. The deposits may be divided as follows:

"(1) Fissure veins in the granite, carrying principally gold and silver with some copper, lead, and zinc.

"(2) Replacements in the quartzite, consisting of bodies of zinc blende and galena, also narrow veins carrying gold and silver.

"(3) Replacements in the limestone, comprising large bodies of zinc blende and considerable deposits of chalcopyrite and pyrite."

According to Henderson the value of all the metals produced in Eagle County from 1880 to the end of 1920 is $23,834,838. The ores mined here are the same as those produced in the Leadville district, and the field has had a somewhat similar experience, on a much smaller scale. The camp started as a silver-lead camp, but a little gold also has been mined. The mines produced about $1,500,000 a year in 1883 to 1886. In 1896 copper began to be mined, and in 1905 the zinc mined became of sufficient value to be noted in the reports of production. In this camp, as at Leadville, zinc sprang into prominence in 1914, and in 1915 it led all other metals in the value of its output, which amounted to $1,381,577.

A. ROCHES MOUTONNÉES.

The great glacier that originated near the Mount of the Holy Cross flowed down Cross Creek, rounding and polishing every projecting point of the granite rock. Such rock forms, owing to their fancied resemblance to the backs of sheep, are called by the French "roches moutonnées." Photograph by W. H. Jackson.

B. EAGLE RIVER CANYON.

An eastbound train passing through Eagle River canyon. View from a point near Belden, looking upstream. The remains of old mines are visible just below the top of the canyon wall in the distance. Photograph furnished by the Denver & Rio Grande Western Railroad.

A. EAGLE VALLEY NEAR EDWARDS.

Although most of the valley of Eagle River between Minturn and Walcott is more than 7,000 feet above sea level, good crops of alfalfa, the more hardy grains, and potatoes are raised. The ranch buildings are usually substantial and the ranches well kept. In the soft light of the evening the fields of waving grain make a very pretty picture. Photograph by M. O. Leighton.

B. RECENT VOLCANO IN EAGLE VALLEY.

From the dark hill in the middle background came the last volcanic outburst in this part of the country. Fragments of dark lava still cling to the slopes, showing that the lava flowed down to the bottom of the valley. Photograph by Marius R. Campbell.

C. EDGE OF RECENT LAVA FLOW.

The lava flowed out from the volcano shown in *B* until it reached the river; there it stopped. This is a view of the edge of the flow where it is washed by Eagle River. Photograph by M. O. Leighton.

result is that the quartzite steadily approaches railroad level downstream. About half a mile below milepost 297 the quartzite reaches railroad grade, and a short distance below it passes beneath the stream and is lost to view.

Just before reaching Rex siding the traveler may see on the west (left) a ridge of loose boulders, which seems almost like a dam thrown across the valley of Eagle River. Doubtless he has already learned to recognize such an accumulation of boulders as a moraine that was pushed out by a glacier from some side valley. This moraine was built by a large body of ice which descended Cross Creek from the high peaks of the Holy Cross group of mountains. The boulders were carried entirely across the valley of Eagle River, showing that the ice filled the valley to the foot of the slope on the east side. The glacier expanded when it reached Eagle River, so that its extremity must have resembled a fan, and it covered the area on which the railroad has been built for a distance of $2\frac{1}{2}$ miles. One of the great blocks of gneiss which it carried to the foot of the slope on the farther side may be seen on the east (right) of the track near Elk Creek. It is 40 feet long and 25 or 30 feet wide, and its top stands 12 feet above the ground.

Cross Creek is noted for the peculiar forms that were produced along it by the passage of the glacier over its granite bed. As the glacier found the floor of the granite canyon somewhat irregular its principal work was to round off and polish the projecting knobs. The rounded masses of granite in this canyon, called "roches moutonnées" (rōsh moo-ton-nay′), are shown in Plate LV, *A*. This name has been applied by French geologists to such rounded rocks on account of their fancied resemblance, when seen at a distance, to the backs of sheep.

At Rex siding the top of the quartzite is at railroad level, and the Leadville limestone may be seen on the left, where it forms several knobs. Its color is light blue, and it is easily distinguishable from the quartzite, which has a yellowish tone. As the railroad swings to the east and the rocks dip in the same direction the Leadville limestone soon disappears below the bottom of the valley, and the only hard rocks in sight are the Carboniferous sandstones and shales, which give to the slopes on the east (right) their banded appearance.

One of the most noteworthy features of this part of the Denver & Rio Grande Western Railroad is the Mount of the Holy Cross (Pl. LIII). This peak stands near the head of Cross Creek, but unfortunately no good view of it can be obtained from the train. Near the mouth of Elk Creek, however, a fleeting glimpse of the mountain may be had, if the traveler is on the alert and looks in the right direction. As the train swings eastward and approaches

the mouth of Elk Creek the traveler, by looking back on the west (left) may see high rugged peaks coming one by one into view. Mount Jackson may be seen by looking up Cross Creek, but the one peak which he desires to see more than all others is hidden for a long time by the high plateau on the south side of the canyon. Finally, however, after crossing Elk Creek, which comes in from the east, when the train is near milepost 300 and just before it passes behind a ridge on the left, the traveler may catch a glimpse up the creek valley of the Mount of the Holy Cross (see Pl. LIII), but even here the cross itself is not well shown. Very few persons who have passed over this road have been able to identify this famous peak, but if the traveler will look as directed he can certainly see it unless the atmospheric conditions prevent a view of any of the high mountains.

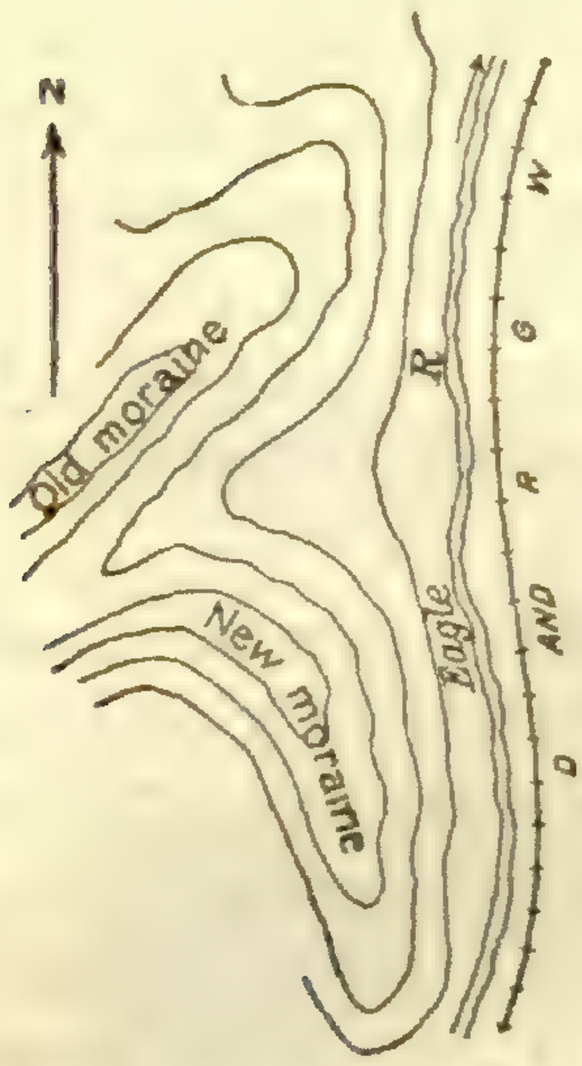

FIGURE 30.—Sketch map showing old and new moraines above Minturn.

Just after milepost 300 is passed the moraine that marks the other limit of the Cross Creek glacier appears across the river as a sharp and distinct ridge which curves parallel with the railroad, and a good view of its tree-covered slopes may be had from the train. This moraine is composed of sand, clay, gravel, and boulders brought down by the ice from the high mountains on the west, and the glacier that brought this great mass of material marked the last stage of glaciation (Wisconsin) that affected North America; but half a mile beyond milepost 300 there is on the west (left) another ridge or moraine that is rudely parallel to the other ridge just described, but sharply distinct from it. This outer moraine was evidently formed long before the last glacier occupied the valley, for its slopes are more affected by the weather, and as it is outside of the other moraine it must have been formed earlier or else the ice would have demolished the inner ridge, which now is the more conspicuous of the two. The relative position of the two moraines is shown in figure 30. The existence of this older moraine shows clearly that glaciers were formed in these mountains in at least two distinct epochs of time, one of which was much earlier than the other.

The rocks that are so well shown in the mountain slope on the east (right) are supposed to belong to the lower part of the upper Carboniferous or, in other words, to have been formed at the same time as the earliest of the great coal beds in the Appalachian region and the Mississippi Valley. In the Rocky Mountains some coal beds have been found in these rocks, but most of them are too small or too im-

pure to be worked profitably. The lowermost of these formations is the Weber shale, which lies directly above the Leadville limestone but which is so soft that it makes no showing at the surface. Above the Weber shale lies 200 or 300 feet of sandstone and shale that have a strong reddish tint, and above this for 1,000 feet or more the rocks consist mainly of light-colored sandstone separated by layers of shale. On account of this alternation of rocks the hillside appears to be ribbed horizontally by beds of white rock.

As the railroad curves back toward the west the river cuts into the Leadville limestone. The rock is first seen near milepost 301, but it rises steeply and at the milepost is 30 feet above the track, Here the direction in which the beds of rock trend or strike begins to be affected by the northward plunge of the Holy Cross anticline,[37] so that the Leadville limestone, instead of becoming higher and

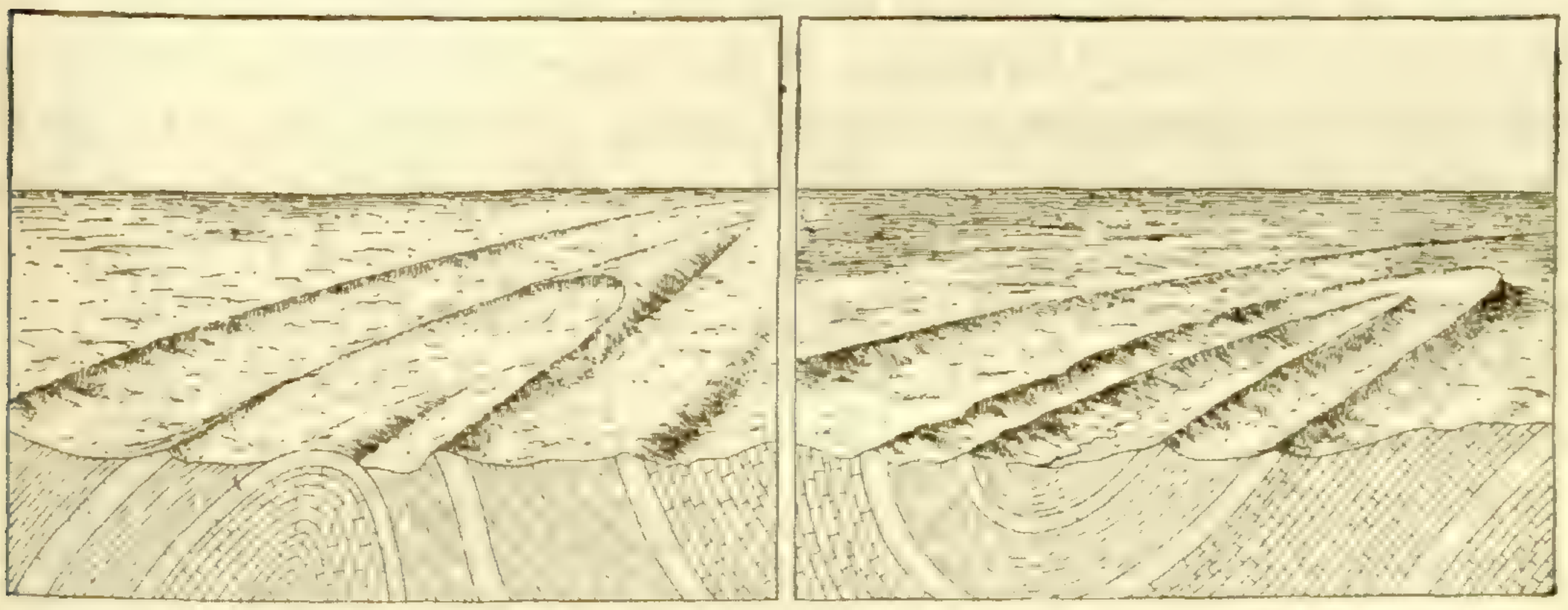

FIGURE 31.—Anticline (at left) and syncline (at right). Perspective views and vertical sections showing the half-cigar-shaped mountains of hard rocks on the anticline and the canoe-shaped point of the syncline. After Willis.

higher as the train descends the valley, dips down the stream, and before the train reaches Minturn the beds are below water level.

The town of Minturn is built on a broad, flat valley bottom in which no hard rocks are exposed, but a mile below the station the same beds of rock which before were seen only in the cliffs on the east form the mountain side on the west, showing that the beds of rock are swinging more toward the west than they do farther up the river. The red sandstone that was so conspicuous above disappears on the right about the mouth of Gores Creek. This creek is a clear mountain stream that heads in the high peaks of the Gore Range on the east, some of which may be seen by looking directly up its valley. The stream is noted for

Minturn.

Elevation 7,825 feet.
Population 298.
Denver 302 miles.

[37] An upward bulge or fold of the rocks is termed an anticline; if it is long and narrow it is frequently called an arch, but if it is short and nearly circular in outline it is called a dome. The corresponding downfold is called a syncline. These folds are represented in figure 31.

the fine fishing that it affords and that tempts many anglers to come here to try their luck. The double track which begins above Redcliff ends just below the bridge over Gores Creek.

At the point where the red sandstone and shale pass below railroad level near Gores Creek the cliff on the right is composed of the overlying light-colored sandstone and interbedded darker shale. At the mouth of the creek these beds dip about 30° NE. A short distance below the mouth of the creek the river bends sharply toward the east, and in so doing it cuts more directly across the hard ledges of sandstone which compose the bulk of the formation. As these rocks are harder than those either above or below, the canyon cut by the river is narrower and more rugged than it is in the vicinity of Minturn or below that place, where the beds are much softer. After making a great curve to the right the sandstones (Weber formation) abruptly come to an end. As the train passes this point the traveler may not fully realize why they terminate at this place, but the map will show him that their disappearance from the east side of the river is due to the fact that they swing across the stream, although they do not show in the hillside on the west. If the traveler looks back after passing down the valley a mile or so he will see these beds on the east side of the valley dipping about 45° NE. and reappearing on the west side, as described above. The beds that overlie the sandstone are very soft and consist mostly of clay or shale with here and there a more sandy layer that makes a ledge along the hillside. The beds are so soft that they have been worn down into comparatively low hills, at least near the river, and the slopes are everywhere round and gentle. These rocks are the same as the variegated sandstone and shale at Leadville, which have been called the Maroon formation.

Immediately below the mouth of the canyon the river bottom, which expands to a width of about half a mile and holds it for a distance of several miles, is strewn with boulders brought down by the stream. These boulders extend for about half a mile, and below that point the valley, although narrow, is well irrigated and farmed. The hills on the west side of the valley bear no resemblance in form or color to those on the east. They are dark and their surfaces are hummocky, as if composed of soft material that has slid down the hillside until it resembles a gigantic moraine. The reason for the peculiar appearance of this hillside is not apparent until the traveler has passed the little village of Avon and has looked back on the other side of the hill. The rocks here are well exposed by the cutting of the stream that comes down out of the high mountains on the west. At the base they consist of the ordinary country rocks with which the traveler is already familiar. Above these rocks lie some darker ones, composed

Avon.

Elevation 7,465 feet.
Denver 308 miles.

of volcanic material that was long ago washed down to this position from a lava flow. This material, which is soft and easily washed by the rains, has slumped down the hillsides until it has given the surface a general hummocky appearance.

The valley at Avon is nearly a mile wide, and in summer it presents a beautiful appearance, with field after field of grain rippling in the wind and here and there a well-kept farmhouse peeping from a grove of cottonwood trees. The farms extend about a mile below the village to a point where the bluff on the east side swings in against the river, cutting off the farming land and rendering the valley rough and broken. The railroad, which has been forced to follow the river along the west (left) side of the valley, swings to the right in a broad curve at Edwards siding, just beyond milepost 312, and continues on that side for some distance. As the railroad is high above the river and skirts the bluffs along the east side, the traveler has an unobstructed view of the full sweep of the valley. (See Pl. LVI, *A*.) A large valley comes in from the southwest (left), and soon the high peaks of the Holy Cross Range burst into view. The view near milepost 313 is one of the most attractive on the road, especially in early summer, when the summits are still covered with the snow of the previous winter, or in early autumn, when they are white with the first snow of the season. One can look across the grassy bottom of Eagle River, dotted with herds of cattle, to the ranches on the opposite side, where field after field of grain or hay stretches up the side valley as far as the eye can see and even climbs the opposite slope to the highest terrace. Here and there ranch houses are embowered in groves of trees, and the white schoolhouse, with its bright-red roof, gives a touch of color to the pastoral scene. The green fields, especially when the afternoon shadows begin to lengthen, look like velvet, and one would have to travel far to find a landscape more beautiful.

In the movements that have raised the mountains the soft rocks have been crumpled and folded or crushed and broken in a very complex manner. Just beyond Allenton siding, beyond milepost 314, the beds of rock are magnificently exposed on the east (right), for here an old bend in the river threw it against the foot of the bluff, where it washed away all loose material. Here the beds of rock stand nearly vertical, but within a short distance they show a tendency to flatten and pass with slight dips under the river, which here swings sharply to the right. The traveler can see that the rocks here are prevailingly soft and that only here and there thin beds of sandstone stand out like giant ribs on the face of the cliff. The colors of the rocks are variegated, but there is enough red and deep brown in them to give the hills a warm tint.

Half a mile beyond milepost 315, at the crossing of a small creek which enters the river from the right, the base of brilliant light-red sandstone is exposed. This sandstone is Triassic in age and is much more showy in color than any other rock which the traveler has seen since he left Canon City. On account of its striking color attempts have been made to utilize it as building stone, but generally it is so easily affected by the weather that in a few years the corners are rounded off and even great holes are etched in the solid blocks. Where first seen these beds dip about 45° W., but the dip flattens in a short distance to about 25°.[38] Beyond milepost 316 the top of the bright-red beds may be seen on both sides of the river. On the right they extend down the hillside in a great curve, but on the left they run along the face of the bluff with only a slight dip downstream.

The rocks that overlie the bright-red sandstone are variegated in color but are predominantly green and maroon. They make up

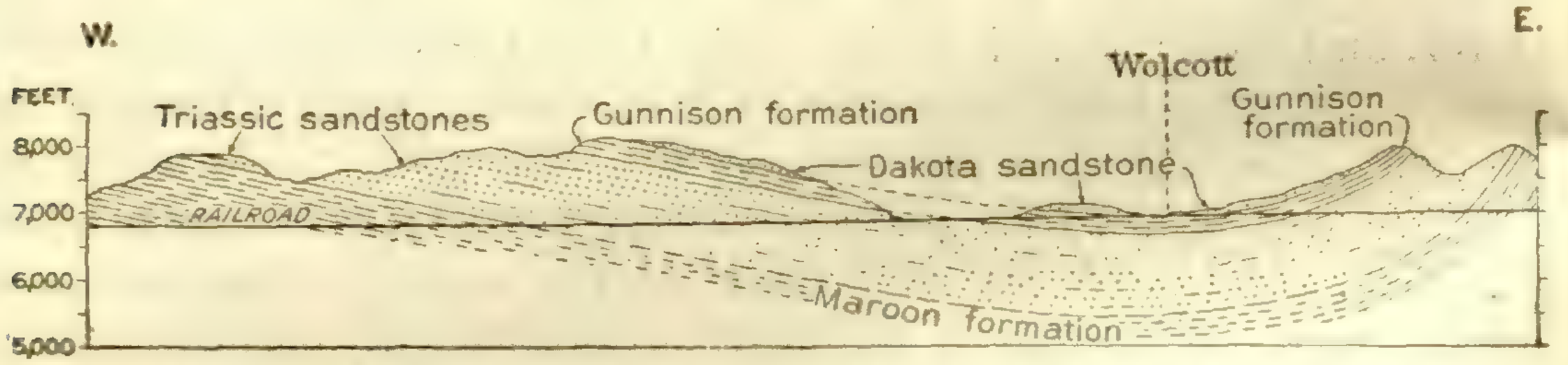

FIGURE 32.—Sketch section across the syncline at Wolcott on a line from east to west.

what is called the Gunnison formation, so named from its outcrop in the valley of Gunnison River. The upper part of this formation is without doubt the same as the Morrison formation on the east side of the mountains, but its lower part probably includes rocks that are not found on that side. The Gunnison formation here contains much soft shale and clay but includes also some beds of resistant sandstone. At this place the formation has been so much crushed that its thickness can not be estimated, but at other outcrops in this vicinity, where it is undisturbed, it is about 220 feet thick. The discovery of the remains of some very wonderful

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[38] The peculiarities and irregularities of the dips in this part of the valley can be best understood by reference to the map on page 134. This map shows that the river here cuts diagonally across the rim of a sag or basin in the rocks (not a surface basin), the lowest part or axis of which is crossed by the railroad a mile or so farther north toward Wolcott. On the eastern rim of this basin the rocks stand on edge, as shown by the accompanying diagram, but they flatten rapidly as they pass below water level, and as seen farther on they lie nearly flat along its axis.

The meaning of the dips is well illustrated in the accompanying sketch (fig. 32), which shows the rocks as they would appear in a deep trench cut vertically from east to west through the fold.

animals in the upper part of this formation north of Canon City is described briefly on page 70.

Above the Gunnison formation lies the Dakota sandstone, which crosses the track near milepost 317. This sandstone marks the base of the Upper Cretaceous and is one of the most persistent and widespread formations of the Rocky Mountain region. It extends from northern Wyoming to central New Mexico and from Omaha to central Utah. In the valley of Eagle River it consists of a single layer of brownish-yellow sandstone 30 to 40 feet thick. It slopes up the hillside on the right and forms the crest of a ridge that runs nearly parallel with the railroad for a mile or more. Across the river it forms the northeastern slope of the hill in what geologists call a "dip slope."[39]

The formations so far described are fairly hard, and consequently they form the walls of a rather narrow canyon, but immediately over the Dakota sandstone lies the Mancos shale, which is one of the softest rocks in this region. It is so soft that it readily wears away under the action of the weather and the streams, and consequently it seldom or never forms high or large hills. Where Eagle River crosses the outcrop of the Dakota sandstone and cuts into the shale the valley immediately expands to a width of nearly a mile and contains several ranches. In fact, nearly all the shale on the left side of the river has been removed and the valley takes the form of a rock-rimmed basin. The beds of rock on the east side of the basin are steeply upturned, but those on the west side dip toward the middle of the basin at a very low angle, which can hardly be detected but which may be seen in the cliffs of shale almost directly ahead. This little basin or downfold of Cretaceous rocks forms the extreme southern tip of the great syncline or basin of Cretaceous rocks which carries the valuable coal beds of Routt and Moffat counties, in the northwestern part of the State, and which underlies most of southwestern Wyoming.

As the train passes milepost 317 the traveler, by looking back the way he came, may obtain another glimpse of the high peaks of the Holy Cross Range, which, if they are covered with snow, are still conspicuous objects above the horizon. After the traveler passes the axis of the syncline, between mileposts 317 and 318, he can see the gentle rise of the rocks on the west (left) of the railroad in a great cliff of shale, which is nearly ahead but which may be seen on the left from milepost 318. Some bands of white, impure limestone can

[39] A dip slope is formed by a bed of hard rock from which overlying soft material has been removed by rains and streams, and as the slope of the surface is the same as the dip of the bed that controls the surface it is known as a dip slope.

be followed by the eye, and these indicate clearly the rise of the beds toward the west, but a still better marker of their rise is the Dakota sandstone, which lies below the surface in the central part of the basin but which rises from stream level just below the station at Wolcott and from that place westward forms a battlemented wall along the canyon.

The north side of the valley is marked by a high cliff of the Mancos shale, but the other side is nearly flat and can be cultivated, so that if makes an agreeable break in the line of canyons and narrow valleys through which the traveler has been passing. Until the building of the "Moffat road," in 1906, Wolcott, although but a small village, was one of the principal distributing points for the region to the north as far as the Wyoming line, and a stage was run daily between Wolcott and Steamboat Springs. At that time the region now included in Routt and Moffat counties was noted chiefly as a stock-raising country and thousands of cattle were annually shipped east over the Denver & Rio Grande Railroad from Wolcott and Rifle. Since the completion of the "Moffat road" Steamboat Springs and the region round about receive their supplies directly from Denver, but a stage line is still maintained from Wolcott to State Bridge, 14 miles distant, the nearest point on the "Moffat road."

Wolcott.

Elevation 6,975 feet.
Population 119.*
Denver 319 miles.

On leaving Wolcott the train plunges into another canyon, which extends for a distance of about 5 miles. The Dakota sandstone forms the cap rock of the walls of this canyon, especially on the north side, but the surface back of the rugged cliffs rises gradually to much greater heights. The sandstone appears above railroad level just below the station at Wolcott, where it consists of a brownish-yellow sandstone, about 80 feet thick. It abounds in impressions of stems and leaves of plants, which show that at the time it was deposited the country was covered with trees, many of them similar to those living to-day in the more humid regions of the United States. At that time there were no Rocky Mountains, and the deposition of this sand, which has since been hardened into sandstone, was followed by a great invasion of salt water, which formed a sea that stretched from Iowa to Utah and entirely across the United States from north to south. In that sea lived animals that produced shells much like the shellfish of the present day, and on the death of the animals the shells dropped to the bottom and there became embedded in fine mud. To-day that sea bottom has been elevated thousands of feet above its former position, the sea water has drained away, and the limy muds have been hardened into shale in which the shells are preserved with all their beautiful ornamentation. The traveler can

verify this statement for himself by finding well-preserved fossil sea shells in the railroad cut just east of the station at Wolcott.

The station at Wolcott is built on the Dakota sandstone, which in a short distance to the west rises above track level, so that the underlying variegated shale and sandstone (Gunnison formation) and the rocks still lower in the geologic column come into view as the traveler pursues his way down the river bank. As the train rounds the first sharp curve below the station the variegated beds of the Gunnison formation may be seen on the north (right), where they have been exposed by the cutting for the railroad track. About a mile below the village the Dakota lies about 300 feet above the level of the track and the light-red sandstone of the Triassic makes its appearance at that level, but it is so poorly shown that the traveler may not be able to identify it. A view down the river valley from this point, however, shows that the bright-red sandstone is very conspicuous in the cliffs—it is, in fact, the most prominent rock to be seen. The profile of the cliff on the north side of the canyon is represented in figure 33. In this part of the canyon the red sandstone is so brilliant that the outcrop looks like a flame or a mass of red-hot iron on the hillside. At Kent siding, just beyond milepost 321, the valley is somewhat wider than it is farther upstream, and the traveler may obtain, on the north, an excellent view of the canyon wall, which is about 175 feet high and is capped by Dakota sandstone and the brownish-red sandstone that marks the top of the Triassic system of rocks.

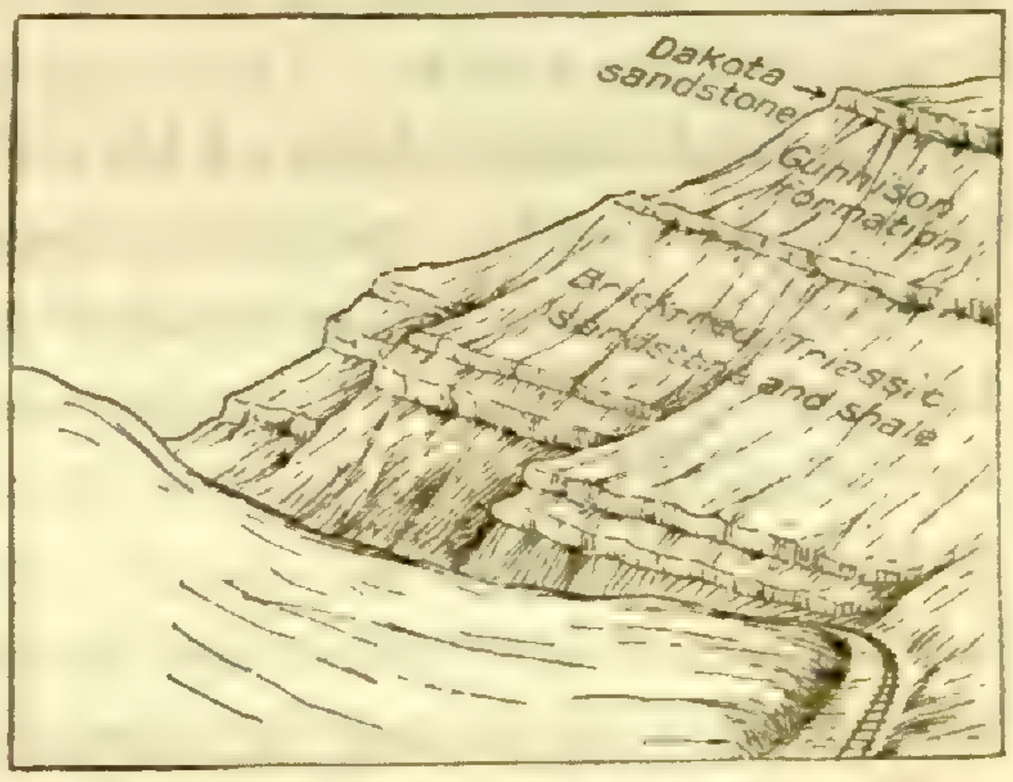

FIGURE 33.—Canyon cut by Eagle River through the west rim of the syncline, as seen from Wolcott.

Although the canyon is in general very narrow there are at some places along the river level lands and small farms. The stream, like all others in this region, is fringed with cottonwood trees and willows, but among these are interspersed dark spruce trees, which give a pleasing contrast. In summer there is a decided difference between the dark-bluish tint of the spruce trees and the soft green of the cottonwoods and the willows, but the color effects are at their best in early autumn, when the leaves of the cottonwoods and the willows are a brilliant yellow.

Owing to the westward rise of the rocks the canyon walls grow higher and higher, but near Ortega siding (mileposts 323–324) the Triassic red sandstone rises above track level and the canyon ends, because as soon as the hard beds rise above drainage level they are undermined by the cutting away of the soft shale of the lower (Ma-

roon) formation. The canyon is in places rugged and picturesque, but generally it will be remembered for its brilliant coloring rather than for the configuration of its rocky walls.

The valley below the canyon resembles the valley cut in the same rocks near Avon, but the hills here are lower than those about Avon and are cut more deeply by the tributary streams. The main valley, however, contains few striking scenic features, but it is interesting for its many fine farms and comfortable residences.

Near milepost 327 the band of bright-red rock on the higher hills across the river is very conspicuous. As shown on the map, it does not extend far to the west, for it loops around and connects with the exposure that was crossed a few miles above Wolcott. Toward the north the Triassic rocks extend for a long distance, but they are not visible from the train. The traveler may be able to trace the Dakota for some distance, but it eventually fades from sight, and then the most prominent rock is a dark basalt that caps the highest hill 6 or 8 miles to the north. This rock is a remnant of what was once probably a continuous sheet of lava that was poured out on a nearly level surface before the present canyons were cut, when the general surface of the country coincided with the tops of the present highest hills and plateaus. It should not be supposed, however, that the surface at that time was higher above sea level than it is to-day; indeed, it may have been not nearly so high, for it may have been raised to its present level since the lava was poured out. Other remnants of this sheet of lava may be seen farther down Eagle River.

The thriving village of Eagle stands at the junction of the valleys of Brush Creek and Eagle River, in the midst of a rich agricultural district, which presents a pleasing contrast to the bare rocks of the canyon walls and to the badlands that the streams have produced in the bluffs bordering the main valley. Although the general altitude of the valley is rather high, good crops of hay, grain, and potatoes are raised, and much live stock finds pasturage on the surrounding uplands. The railroad crosses Eagle River just before reaching Eagle and remains on the south side of that stream as far as its junction with Colorado River.

Eagle.

Elevation 6,598 feet.
Population 358.
Denver 329 miles.

After leaving Eagle the traveler may obtain another glimpse of the Holy Cross Mountains on the left, up the broad valley of Brush Creek. For some distance below this point the bluffs of the river are so high that they shut out from view the country on the south (left), but farther west the bluffs recede from the river and grow lower and lower until the upland on the south is clearly visible. This upland now takes on the aspect of a broad, sloping plateau that culminates in the Holy Cross Mountains, which form a most

striking feature, especially when they are covered with snow and the intermediate country is still clothed in its summer verdure.

The Holy Cross Mountains are usually regarded as the westernmost range of the Rocky Mountains. The traveler who is pursuing his way along the bottoms of these canyons may not be aware that he has passed out of the Rocky Mountains and has entered a province marked by very different surface features, but if he could obtain a comprehensive view of the country from some high point he would see at once that the great ranges of the Rocky Mountains lie entirely to the east, and that although mountain ranges are visible to the west they are neither extensive nor continuous. The region into which he is now entering is a land of plateaus, some low and some high—nearly as high as the peaks of the Rockies. It is also called a land of canyons, for it includes most of the canyons of the Colorado River system. Country of this type extends westward from the Holy Cross Mountains to the west side of the Wasatch Plateau in the vicinity of Provo, Utah.

For about 6 miles below the town of Eagle the valley of the river continues much the same as it is about the town. The railroad is built on a terrace that stands 60 to 80 feet above the river, and in places this terrace is surmounted by another about 50 feet higher. The bluffs on the north side of the valley become conspicuous because of their barrenness and because they are being rapidly dissected by rivulets produced by every shower. Gypsum Creek, another large stream, enters the main valley from the south at the village of Gypsum. The creek and the town are so named because of the occurrence in abundance of the mineral gypsum in the neighborhood. The village of Gypsum is a supply point for large districts both to the north and to the south. The region near the village is devoted largely to farming, but beyond the farms there is a large area of open range, upon which a great number of cattle are fattened each year.

Gypsum.

Elevation 6,325 feet.
Population 470.*
Denver 336 miles.

The red sandstone of the Triassic comes into the tops of the hills below Gypsum, and as it is the hardest rock in the series exposed here it tends to form a canyon that has high and apparently precipitous walls. Near milepost 337 the railroad enters the canyon, which is not so narrow as it at first appears. This canyon is not so picturesque as the canyon in similar beds below Wolcott, for in the canyon below Gypsum the hard red sandstone lies high in the hills and is underlain by soft clay and shale, which wear away rapidly, so that the harder sandstone above breaks down, forming a long, gradual slope back from the stream, whereas in the canyon below Wolcott there are no soft beds exposed below to be eroded and to undermine

the harder rocks above, so that the red sandstone cliffs rise almost directly from the water.

As the traveler enters the canyon below Gypsum he may see that the bright-red beds lie in the form of a downfold (syncline)—that is, they are higher at the ends of the canyon than in the middle. This structure may not be apparent to him at first, but at a point between mileposts 338 and 339 he may easily see that the red beds directly opposite the train are lower than the same beds are either to the right or to the left. This lowest point is called the axis of the syncline; it is the line toward which the beds dip from both sides. The layer of rock at the extreme top of the hill on the right is dark brown and not red like the underlying beds, and it does not lie parallel with the other beds but caps the hills without conforming to the dip of the beds beneath. The dark rock is so far away that the traveler can not distinguish its character, but if it were nearer he would see that it is basalt, similar to the sheet of basalt that caps the canyon walls below Wolcott.

In passing down the canyon, before he arrives at the junction of Eagle River and Colorado (Grand) River, the traveler has spread before him one of the finest examples of a recent lava flow that can be found in this country. He can first see this lava flow in the distance on the right soon after he passes milepost 340, in a low, dark hill in the bottom of the valley. The rock of this hill may not at first attract his attention, but on approaching it nearer he can see that it is nearly black and presents a striking contrast to the light-colored rock of the sides of the valley. This rock can be seen at close range at a point about half a mile farther along, where it forms a terrace across the river bottom which suggests that the valley was at one time filled up to a certain level with this black rock. On closer inspection this black rock is seen to be very rough and broken (see Pl. LVI, *B*), and those who are familiar with lava flows will at once recognize its character, though others may have difficulty in realizing that this mass of rock was once molten matter that was forced up from the interior of the earth through some vent in the solid crust and that flowed down into this valley much as thick molasses flows in cold weather. This fiery mass could not flow rapidly, for its outer part was continually cooling and being "frozen" into solid rock. The crust thus formed would hold the lava for a time, but it would finally burst and the fiery flood would once more roll along until it was again held up by the cooling of the surface. This drawing off of the liquid lava produced caverns beneath the solid crust, which in time broke and fell in, so that the surface is now very rough. The edge of the flow, shown in Plate LVI, *C*, can be seen from the train as it follows the bank of Eagle River on the opposite side.

The traveler has now seen the lava flow, though he has probably not seen the vent or volcano from which it must have come, but if he scans closely the hills across the valley he will see that some of them are littered with fragments of the same dark rock that composes the flow and that others consist wholly of that rock. The volcano must have been near the top of the first series of hills, as shown in Plate LVI, *B*, but its crater is now obscured by the lava that consolidated in its throat. The vent was small, but it has all the essential features of a true volcano. The ravine down which the fiery flood rolled into the valley, leaving some of the melted rock adhering to its sides as it passed, may be seen from the train. (See Pl. LVI, *B*.)

This eruption seems to have been the last expiring gasp of forces that long before poured out immense floods of molten material in this region. The material erupted at this place was only enough to fill the valley to a depth of 50 or 60 feet but not enough to turn the river from its course. The lava extends down the valley half a mile beyond milepost 341.

As the train rounds the bend, just below the limit of the lava flow, the valley of Colorado River is visible on the north (right), and Eagle River unites with this stream a few hundred yards farther on, but the junction is not near enough to be seen from the train. Colorado River has its source on the east slope of Mount Richthofen, in the northern part of Middle Park, and those who went to the summit of the mountains (Corona) on the "Moffat road" could look down on this west side into some of the head tributaries of this river. After flowing westward across Middle Park the river escapes from that natural basin in the mountains by Gore Canyon, a rugged gorge which it has cut through the Park Range—the same range which the traveler saw on the east (right) at Tennessee Pass. Gore Canyon is cut in granite, but below the Park Range the valley is much like that of Eagle River, consisting of a succession of narrow canyons with stretches of broad valley between. This alternation is repeated many times along the river before it is joined by Eagle River at the siding of Dotsero. At the point of junction there is visible far to the north a high plateau, which is locally called The Flattops or the White River Plateau, from the stream that drains its western slope. It has an altitude of 11,000 to 12,000 feet and is noted as the greatest hunting ground of western Colorado. It was here that Theodore Roosevelt made one of his famous hunting trips while he was President of the United States. The preservation of the plateau at this high altitude is largely due to the fact that soon after its even surface was formed it was covered from some vent in this region with lava, which afterward cooled and consolidated into a basalt that has successfully withstood the action of the elements

and still preserves its nearly level surface. The lava sheet that caps the high hill on the north side of the canyon below Wolcott was probably once a part of this same flow or flows but has been separated from it by the canyon cut by Colorado River.

After passing milepost 342 and a small cut a few hundred yards beyond the railroad track reaches the bank of Colorado River, which it follows to the western border of Colorado. This part of the country is noted for its cattle and horses, and the siding of Dotsero is maintained largely for their shipment. There are no red rocks in the valley of Colorado River just below the mouth of Eagle River, but the rocks there exposed are about as hard as the soft red and green shale and sandstone above. At first the traveler may not be able to identify any of the dull-gray and slate-colored rocks below Eagle River with those he has seen farther upstream, but a comparison of the section and of the order of the formations may show him that these beds are the same as the heavy cliff-making sandstone and shale which he saw just below Minturn. It might be supposed that the same formation should show the same composition and hardness wherever it is exposed, but as these formations consisted originally of sand, clay, and limy materials that were deposited in some body of standing water, either a lake or the sea, it is apparent that the character of the formation at any place must depend largely upon the kind of material there swept into the body of water by the streams, and as the land near by was probably composed of various kinds of rocks, which furnished various kinds of material, it does not seem strange that at one locality a formation may consist largely of sandstone and at another of shale. Changes from sandstone or shale to limestone are more rare, but such changes are observed in many parts of the country. The soft materials, including some coal beds that are exposed below Eagle River, belong to the Weber formation, which is in the lower part of the upper Carboniferous rocks.

Dotsero.

Elevation 6,167 feet.
Denver 343 miles.

The rocks rise gently westward, and at milepost 345 the massive layers of the Leadville limestone rise from river level. This point marks the beginning of one of the most noted canyons on the line of the Denver & Rio Grande Western Railroad, the canyon of Colorado River that stretches in unbroken beauty and grandeur from this point to Glenwood Springs, a distance of 15 miles. (See Pls. LVII, *B*, LVIII, and LIX.) This great canyon was trenched by the river in an immense upfold of hard beds, which include all the sedimentary rocks that the railroad has crossed in the canyons above, and into the underlying granite, to a total depth of 800 to 1,000 feet. The first appearance of the Leadville limestone, noted above, near milepost 345, is marked by a warm sulphur spring, very similar to

A. MOUNTAIN SHEEP.

Occasionally during the winter mountain sheep may be seen on the cliffs in the Colorado River canyon. The deep snow drives them down from the higher tops, and they find pasture on the narrow ledges along the canyon wall, from which they may gaze on the passing trains.

B. UPPER END OF CANYON OF COLORADO RIVER.

The regular masonry-like walls are the striking feature of the upper end of this beautiful and picturesque canyon. The beds of quartzite are so even and continuous that they seem to have been dressed and laid by man. The walls rise abruptly from the river, so in building the automobile highway it was necessary to tunnel through these beds at some points. Photograph by the Detroit Publishing Co.; furnished by the Denver & Rio Grande Western Railroad.

CANYON OF COLORADO RIVER.

In the part of the canyon a short distance above Shoshone there are many beautiful vistas of quiet stretches of river between the rugged walls of quartzite towering on either side. The rocks rise steadily downstream, and the granite makes its first appearance in the railroad tunnel through the projecting point on the left. Photograph copyrighted by the Detroit Publishing Co.; furnished by the Denver & Rio Grande Western Railroad.

the warm springs which gush from the same formation at Glenwood Springs and give that place its reputation. Why the water should be warm at both these places is a question that can not yet be answered, for neither spring has any apparent connection with a fault that would permit the hot waters to rise from great depths, or with old volcanic flows or vents in which circulating water would come into contact with rocks that still retain some of the heat they had when they were ejected from the earth's interior. However, there may be some underground connection with one or the other of these features which is not apparent at the surface but which would account for the temperature of the waters carried in this limestone.

The limestone rises toward the west at an angle of about 15°, and within a distance of half a mile the underlying quartzite appears at the level of the track. As the river cuts deeper and deeper into the rising rocks the canyon becomes more and more rugged, and the short bends give rise to many towers and pinnacles upon the projecting points. As the rocks continue to rise in the direction in which the train is going, lower and lower rocks come into view. Next below the upper quartzite, which is about 100 feet thick, lie shale and thin-bedded sandstone, about 40 feet thick, and upon these lies white quartzite, about 270 feet thick. So far the section in this canyon is almost identical with that seen in the deeper canyons up Eagle River, but here there is still another member, which seems not to be present farther east. This member is a coarse quartzite whose chief characteristics are its rich pink or maroon color and the remarkable regularity in the thickness of its various beds, as well as the evenness of the bedding planes which separate them. These characteristics are well shown in Plate LVII, *B*. The full thickness of this quartzite can not be seen here, for within a short distance the beds dip sharply in the other direction and the quartzite disappears below water level. Farther down the river, however, where the quartzite rests on the granite, its thickness is about 80 feet. The highest point on this arch in the rocks is reached about half a mile beyond milepost 346. Beyond this point the beds dip rather steeply downstream until the Leadville limestone is at track level on the left, and then the whole series is broken by a great fault, which, as shown on the map, crosses the railroad at milepost 347.

Beyond the fault the land on both sides of the river is comparatively low and smooth, and then the Leadville limestone rises again from track level. Where it is seen by the roadside it is much broken, having evidently been greatly disturbed and crushed. The rise of the formations downstream is gradual but steady, so that near milepost 349 all the sedimentary rocks are again above water level and the granite makes its appearance. Plate LVIII is reproduced from

a photograph taken at this point, looking downstream. The first tunnel near milepost 350 is cut in the massive granite, which continues to rise higher and higher in the canyon as the train proceeds.

The part of the canyon in which the base of the quartzite is only a few score or few hundred feet above water level is its most interesting and picturesque part, which is all too soon passed by the trains. The canyon walls are nearly vertical, and the cliffs formed of the quartzite stand up like immense architectural structures and present great variety of form and color. The joints, which cut the rocks in at least two directions, give rise to smooth vertical faces of rock and to buttresses and minarets almost without number. The canyon here is narrow and tortuous, and many magnificent vistas can be had of the swiftly flowing river and the dark walls, which even at midday seem to envelop the deeper parts with a somber haze.

From this apparently interminable narrow labyrinth the traveler at length emerges into a more open part of the canyon, where he may well be surprised to find dwelling houses and the station of Shoshone. (See sheet 5, p. 150.) Here is the intake of the great hydroelectric plant of the Colorado Power Co., whose transmission lines the traveler may have seen near Leadville and near Idaho Springs, west of Denver. The river is dammed at the small railroad tunnel just below Shoshone, and the water is carried through a tunnel cut in the solid rock to the power plant, which is 3½ miles farther down the canyon.[41] The traveler may not realize the quantity of water carried in this tunnel, but if he is making his journey in summer he is soon aware that practically all the water of the river has disappeared into the open mouth of the tunnel.

Shoshone.

Elevation 6,119 feet.
Denver 350 miles.

The general attitude of the rock beds in this canyon and the adjacent plateaus on the north and south is shown in figure 34, which represents them as they would appear in a deep trench cut across the canyon at Shoshone. The beds dip to the south, and the Leadville limestone forms the surface of much of the plateau on the north, but the limestones and sandstones on the south are covered by a great

[41] In the canyon near Shoshone the Colorado Power Co. has built a large plant for generating electricity by water power—a hydroelectric plant. By means of a diversion dam built just below the station the water of Colorado River is turned into a large concrete-lined tunnel, which carries it along the north wall of the canyon for 3½ miles. When flowing at its full capacity this tunnel will deliver 1,250 cubic feet of water every second to immense steel tubes called penstocks, into which it is dropped to river level, 175 feet below. In its fall it drives two large turbine wheels with a total capacity of 18,000 horsepower, which in turn drive generators of 14,000 horsepower. The electric current is transmitted at a voltage of 100,000 through wires carried on high steel towers for a distance of 180 miles to Denver and is used also at several intermediate points.

GEOLOGIC AND TOPOGRAPHIC MAP

OF THE

RIO GRANDE ROUTE

From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
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1922

EXPLANATION

		Age	Thickness in feet
A	Mountain glaciers as they were during the Great Ice Age	Pleistocene	
B	Gravel, sand, and clay	Pleistocene or late Tertiary	
J	Dark marine shale (Mancos shale)	Upper Cretaceous	2,800±
M	Brown sandstone (Dakota sandstone)	Upper Cretaceous	80±
N	Variegated shale and sandstone (Gunnison formation)	Cretaceous (?) and Jurassic	250
P	Brick-red sandstone	Triassic	1,200±
R	Red sandstone and shale (Maroon formation)	Carboniferous (*Pennsylvanian*)	1,900
S	Red sandstone, conglomerate, and shale (Weber formation)	Carboniferous (*Pennsylvanian*)	4,000
U	Blue limestone (Leadville limestone, Ouray limestone)	Carboniferous (*Mississippian*) and Devonian	150
V	Limestone and quartzite: Parting quartzite; White limestone; Lower quartzite (Sawatch quartzite)	Ordovician and Cambrian	270 to 500
X	Granite	Pre-Cambrian	
Y	Lava flows (basalt)	Tertiary	

Fault

The limestone of lower Carboniferous (Mississippian) and Devonian age in the canyon of Colorado River is called Ouray limestone, but it is approximately the same as the Leadville limestone

sheet of basalt, which is not visible from the train but which completely conceals the underlying rocks. A few miles north of the river there is a break (fault) by which the beds on the north are raised higher than those on the south.

Below Shoshone the canyon is cut so deep in the granite core of the great anticline that the sedimentary beds which overlie the granite can be seen only here and there. The traveler may get occasional glimpses of the rim of the canyon and may be surprised to see that the country into which the river has cut this deep gash is level or only gently rolling. This region may be regarded as the southern part of the White River Plateau, and the picturesque scenery of the narrow canyon is due simply to the fact that the plateau here is composed of hard rocks, which wear back slowly into moderate and subdued forms. If, however, the crust of the earth remains stationary for a long time—thousands, perhaps millions, of years—even these hard rocks will be worn into a broad valley, bounded by the moderate slopes of low hills. No rocks are hard enough to resist erosion for all time, and it is evident here that Nature has had abundant time at her disposal, and there is no reason to suppose that she will have less in the future or that the future will be greatly different from the past.

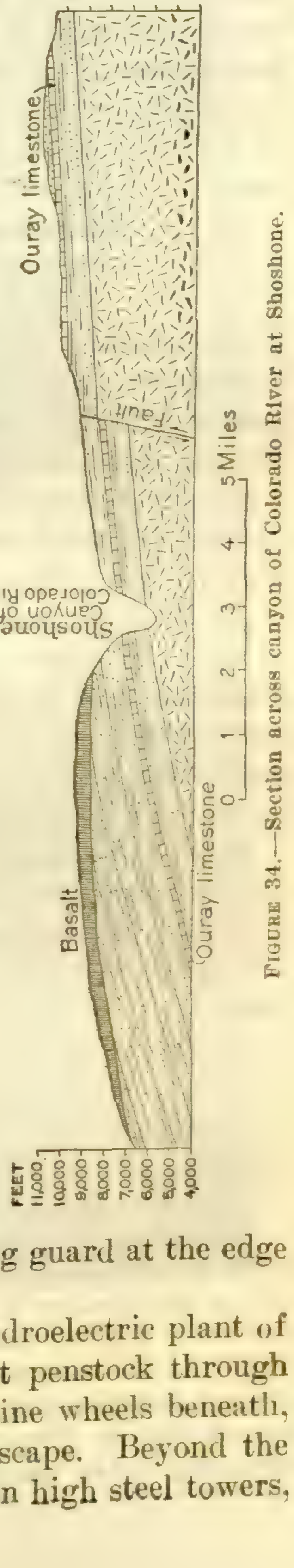


FIGURE 34.—Section across canyon of Colorado River at Shoshone.

The walls of the canyon are rough and rocky, affording excellent feeding ground for mountain sheep when the surface of the plateau is deeply covered with snow. Bands of 40 or 50 sheep are said to be frequently seen in protected places, quietly feeding on the grass and shrubs that grow in the crevices of the rocks and also on the narrow benches on the precipitous slopes. Plate LVII, *A* (p. 132), shows the leader of such a band standing guard at the edge of the cliff.

A short distance beyond milepost 353 is the hydroelectric plant of the Central Colorado Power Co., with its great penstock through which the water is dropped 175 feet to the turbine wheels beneath, and also the spillway for the excess water to escape. Beyond the plant may be seen the transmission line, strung on high steel towers,

spanning gulches, and finally scaling the south wall of the canyon. The line takes a short cut for the valley of Roaring Fork, up which it is carried to and across the Continental Divide at Hagerman Pass.

So far the geologic structure of the great upfold (anticline) is comparatively simple, having been broken at one point only. The highest point in the fold, the axis, is passed near milepost 354, and beyond that point the quartzite rapidly approaches railroad level, but it is broken by so many faults that few travelers can trace the formations and understand the manner in which they appear and disappear. By the aid of the map, however, those who are interested in geologic structure may obtain a fairly good idea of what has happened here and of the shape in which the rocks were left.

All the formations are regular as far as milepost 355, near Grizzly siding, where the quartzite has been abruptly dropped from a height of at least 350 feet above the railroad to water level. This change in the position of the rocks is the result of a fault,[42] which trends slightly west of north, probably cutting the high bluff on the west side of Grizzly Creek, which here enters the river from the north. Beyond this fault the beds rise gradually until the white quartzite, which is at water level at Grizzly, is above the railroad and the canyon is rough and rugged, as shown in Plate LIX. Half a mile beyond milepost 356 about 50 feet of the pink quartzite has made its appearance. At this point the granite on the opposite side of the river rises to a height of at least 300 feet. This discrepancy marks another fault, which does not cross the railroad but trends nearly east and west directly along the stream. The rocks on the south side of this fault have dropped about 300 feet, or those on the north have been lifted a similar distance.

Beyond the point where the railroad approaches the fault most closely the rocks descend, and within a short distance most of the quartzite has disappeared; but the road here enters Noname Park, and it is almost impossible from the moving train to determine the structure. However, a little farther along the Leadville limestone also dips steeply toward the south and is broken by a fault that runs nearly parallel with the one just described. This fault lies near the south wall of the park. The Leadville limestone is dropped on the north side of the fault and may be seen topping the

[42] As the term "fault" means a break in the rocky strata of the earth and as the breaking is always accompanied by slipping and crushing, one might expect to find the surface of the ground disturbed along a fault. It undoubtedly is disturbed when the movement takes place, but all the faults seen from the Denver & Rio Grande Western trains occurred so long ago that any break or disturbance of the surface they caused has been obliterated by the streams and the weather. Examples of the lack of evidence of faults on the surface are shown in Plate LXXXVII, *A* and *B*.

LOWER PART OF CANYON OF COLORADO RIVER.

This view shows the river at flood stage, when the water is lashed to spray by the boulders that obstruct its channel. Since this picture was taken the new automobile highway has been constructed on the right bank. Photograph furnished by the Denver & Rio Grande Western Railroad.

GLENWOOD SPRINGS.

View from hill back of the town, looking west down the valley. Roaring Fork enters Colorado River from the left. The canyon of Colorado River ends just at the right of the view. Hotel Colorado and the famous hot sulphur-water bathing pool are in the foreground on the right. Dark red sandstone forms the hills on the left and crosses the valley in the distance. Photograph furnished by the Denver & Rio Grande Western Railroad.

cliffs on the south. The stream cuts into the upraised block of strata on the south of this fault, and its south bank is followed by the railroad through many cuts in the quartzite and finally in the underlying granite. About half a mile beyond milepost 358, at a sharp bend of the stream around a narrow point that projects from the south, at least 50 feet of granite is exposed, and the massive layers of the Leadville limestone lie like plates on the hillside across the river. As the Leadville limestone never rests normally on the granite it follows that the fault must lie in the river and has caused the formation of Noname Park.

This fault is the last of the series; and, as the train swings around the sharp bend toward the tunnel, the traveler may see the beds descending rather steeply downstream. Here the stream turns once more and cuts back toward the fault in a sharp curve, but the railroad pierces the rocky point, and when the train emerges from the inky blackness of the tunnel the traveler finds himself passing through the rock formations for the last time. The quartzites disappear first below the stream, and finally the massive ledges of the Leadville limestone; and then the train enters the open valley formed by the erosion of the upper Carboniferous rocks and approaches Glenwood Springs.

Here, on the right, is a grove of cottonwood trees, which surround the bathing pool of hot sulphur water that has made this a famous health and pleasure resort, and one may catch glimpses of the towers of the Hotel Colorado, which stands somewhat higher on the mountain slope and overlooks the lower part of the valley.

Springs are also abundant in the river and beside the railroad track just above the station. Glenwood Springs (see Pl. LX) is at the junction of Roaring Fork with Colorado River. Roaring Fork flows in a broad valley that it has eroded in the soft Carboniferous shale—a valley so broad that it seems like the principal valley. The town is noted for its shade trees and its homes and for its accommodations for the travelers who are attracted here by the reputation of the springs. An added attraction is the famous "Hanging Lake" (see Pl. LXI), which lies high up the slopes of the canyon of Colorado River, about 12 miles from the town. Glenwood Springs might also be called a coal-mining center, for although no coal is mined at or near the town it furnishes an outlet for a great coal field that lies to the south and west. A branch of the Denver & Rio Grande Western Railroad turns to the south at Glenwood Springs and connects with the coal-mining towns of Sunshine and Spring Gulch. Forty miles south of Glenwood Springs and connected with it by rail are the famous Yule marble quarries, which are now sending their output to all the large cities of the East. A notable example

Glenwood Springs.

Elevation 5,758 feet.
Population 2,073.
Denver 360 miles.

of the fine buildings constructed of Colorado Yule marble is the new Lincoln Memorial at Washington. At the town of Marble, near these quarries, there is said to be the largest marble mill in this country.

At a point a short distance west of the station at Glenwood Springs the Denver & Rio Grande Western Railroad crosses Colorado River, and here the mouth of Roaring Fork may be seen on the left. The Ouray (Leadville) limestone, from which the hot sulphur springs issue, may be seen extending to the right for about a mile to a point where it passes into the hills and is lost to view. It is succeeded by the soft shale and sandstone of the Weber formation. The Denver & Rio Grande Western follows the right bank of the river.

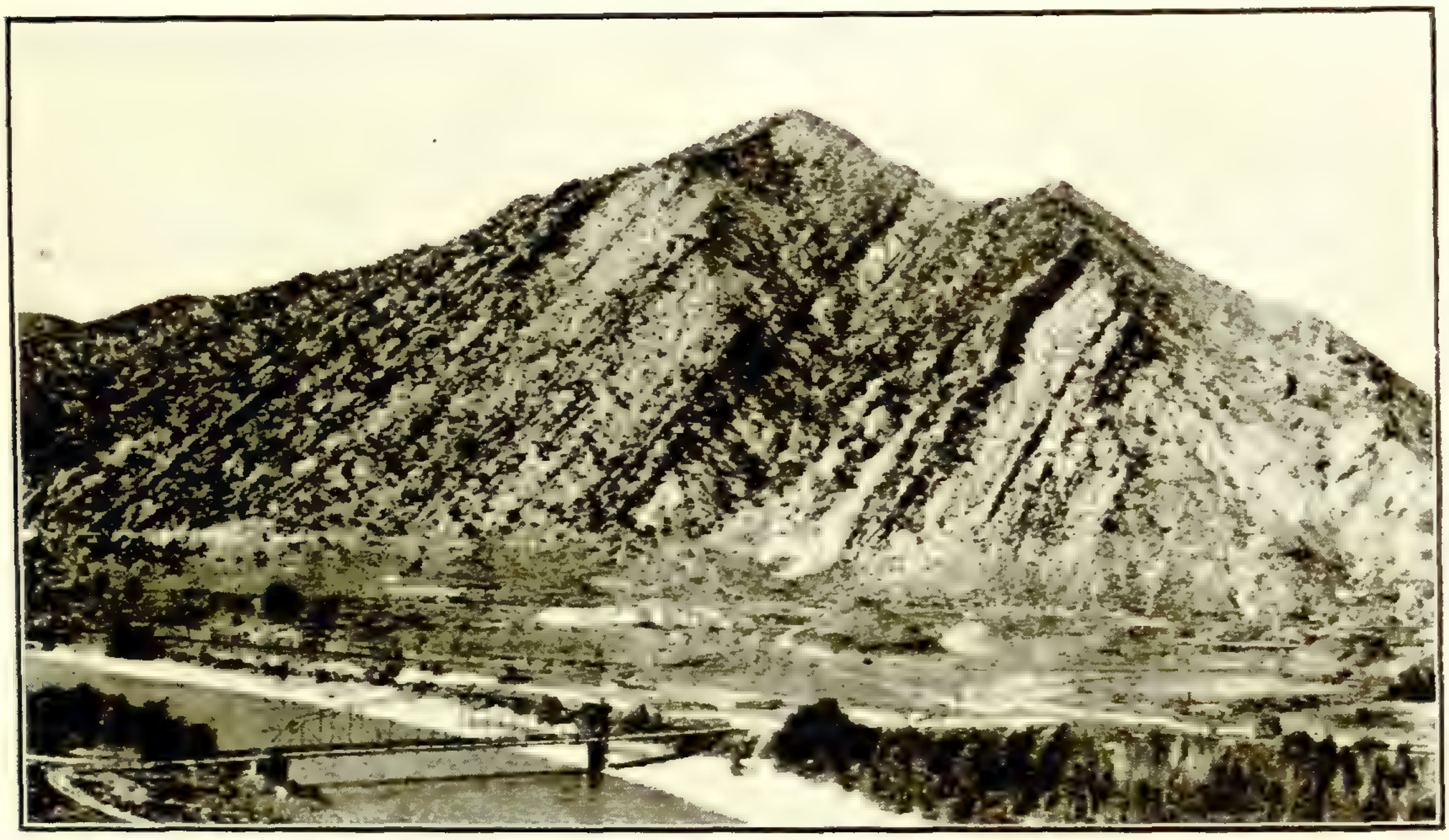
When the train has passed through the railroad yards and is making a rather sharp curve around an eastward bend of the river, the traveler may see Mount Sopris away off to the south (left), framed by the canyon walls of Roaring Fork. Mount Sopris is one of the high mountains in this part of Colorado, and it is one of the most beautiful, because it is a single mass that towers far above the surrounding country.

The mountain side across the river has been gashed by rain and frost, exposing the brick-red Triassic sandstone and shale. The same red beds may be seen on the north side of the river, but before the train reaches them it must cross the maroon, white, and green beds of the Maroon formation. These beds may be seen in the low hills on the north (right) and also in places along the river, where they have been exposed in the excavation made for the road. The brick-red sandstones are the most resistant beds in this part of the series, and the point where the river cuts across them is therefore marked by a canyon which, although not so rugged nor so narrow as other canyons along Colorado River, has a richness and brightness of color that is excelled by few. The base of the Triassic beds is crossed near milepost 364, and the river here cuts nearly through the formation before it turns to the right and follows the strike of the rocks for several miles. At the sharp bend mentioned above the top of the formation is not clearly marked. Usually this formation contains rocks of no other color than brick-red, but a short distance beyond the river there is a band of white sandstone nearly 100 feet thick and then about 300 feet more of a brick-red color. As the brick-red color is generally regarded as the distinguishing feature of this formation the line separating it from the overlying Gunnison shale is drawn provisionally at the uppermost bed that has the characteristic color.

On the river bank opposite milepost 365, which is about half a mile beyond the sharp bend mentioned above, is the tipple of the South Canon Coal Co. The coal is not mined at this place, for the

HANGING LAKE.

A natural wonder on the rim of the canyon of Colorado River about 12 miles from Glenwood Springs.
Photograph furnished by the Denver & Rio Grande Western Railroad.



A. GRAND HOGBACK.

View of the Grand Hogback where it is trenched by Colorado River at Newcastle. Old dump heaps show where coal has been mined, but all the mines have been abandoned. The Wheeler mine, at the extreme right, was abandoned on account of fire, and the coal is still burning. In this hill the workable coal beds have an aggregate thickness of 109 feet. Photograph by Hoyt S. Gale.

B. PALM-LEAF FAN GROWN IN COLORADO.

Long ago in geologic time palms grew luxuriantly in all parts of Colorado, and the coal miners about Newcastle when they want a fan merely quarry one out of the rock. Here is a group of miners and a fossil palm-leaf fan they have just found. Photograph by Hoyt S. Gale.

rocks here are the red sandstone and the Gunnison formation, neither one of which contains coal. The mine is about 1½ miles up South Canyon, in the Mesaverde formation, the great coal-bearing formation of western Colorado, Utah, and Wyoming. In the old geologic reports this formation was called "Laramie," a formation at the extreme top of the Cretaceous system, but it is now known to be very much older than the Laramie and has been named the Mesaverde formation, from the Mesa Verde (may'sa vair'day, Spanish for "green table"), in the extreme southwest corner of the State—a mesa that has now been set aside as a national park on account of its ruined cliff dwellings. The coal is brought from the mine in tram cars.

For about 2 miles below the coal tipple the river follows in a general way the outcrops of the formations, the alternating red and

FIGURE 35.—Top of red sandstone (Triassic), forming crest of hill below South Canon Coal Co.'s coal tipple. Beds dip southwest.

white beds on the mountain side on the left and the beds of solid red color on the right. The beds of sandstone dip steeply to the west, and they stand above the railroad on the right in great slabs 20 or 30 feet high. The surface of these slabs is covered with ripple marks identical with those now being formed in shallow water along the coast, which indicates that the red sand forming these rocks was washed into some shallow basin where it was distinctly rippled by each passing wave. These ripples may have been made millions of years ago, yet they are as perfect as if they had been made but yesterday.

A little below the exposure of ripple-marked sandstone the top of the bright-red sandstone (Triassic) is well shown in a hill across the river. (See fig. 35.)

Near milepost 367 the valley opens and is irrigated, and the deep red of the sandstone is relieved by the bright green of alfalfa, sugar beets, and apple orchards, which are irrigated by water taken from the creek that comes in from the right. Below this point the river turns more toward the west, and it soon cuts through the red sandstone that has bordered the valley most of the way from Glenwood Springs.

As all the beds here dip toward the southwest the river cuts through a formation from bottom to top and then passes into the overlying formation. The top of the Triassic system is crossed at milepost 369, or about three-quarters of a mile beyond the siding of Chacra. The Gunnison formation, the next formation in the series above the Triassic, is only about 300 feet thick, and as it dips at an angle of about 45° it is soon crossed. It is characterized by a variety of colors, but maroon, green, and white predominate. Across the river on the left there are some small conical hills composed of this formation, which are capped on the far side by massive beds of the Dakota sandstone, which marks the base of the Upper Cretaceous series and is one of the most persistent and widespread formations in the Rocky Mountain region. It is generally thin, at few places exceeding 80 feet in thickness. It was deposited on the surface of the Gunnison formation. During the deposition of the Gunnison formation the region was land, though probably of low relief, but the deposition of the Dakota marks the end of land conditions and the beginning of the occupancy of the region by the sea, which continued during the deposition of the succeeding thick shale. The Dakota sandstone is generally massive and very resistant to erosion, so that where it is upturned at any considerable angle it makes hogbacks, such as those seen back of Canon City. Although the Dakota is not exposed near the railroad its beds, concealed beneath the surface, are crossed by the track about halfway between mileposts 369 and 370. The relation of the Dakota to the rocks above is shown in figure 36.

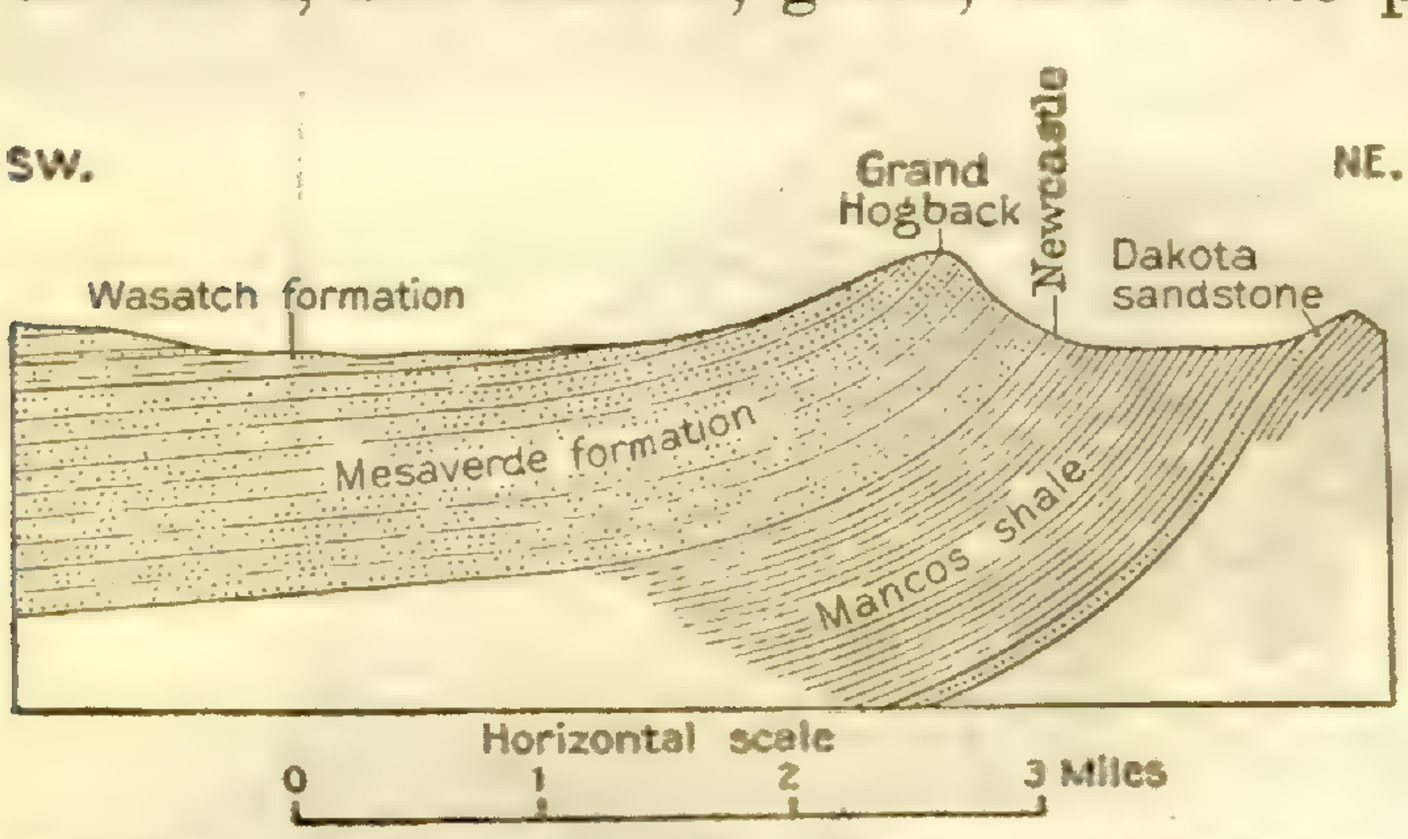


FIGURE 36.—Section through Grand Hogback at Newcastle.

The rocks above the Dakota for a long distance are very soft shale or shaly limestone, so they have been eroded into a wide valley that lies between the little hogback formed by the Dakota sandstone and the mountainous ridge on the left, which trends nearly parallel with the line of the railroad and is composed of the Mesaverde forma-

tion, also of Upper Cretaceous age. The first shale to be seen is exposed in a cut in the side of a hill, but it is so close to the moving train that its character can not easily be determined. It is, however, very limy, and many of its layers consist of soft, white, impure limestone. This formation is the Niobrara limestone, and it is characterized by shells (*Inoceramus*) from 8 to 10 inches in diameter, which occur in great abundance. These shells are of peculiar construction, for the grain of the shell runs directly through it instead of along or around it as in most shells, both fossil and living, and this structure makes the shell very weak and easily broken. At the time this shale and limestone were deposited there were, so far as is now known, no mountains in this region, and the sea had an unbroken sweep from the site of Missouri River on the east to the site of the Wasatch Mountains on the west. Many persons may find it hard to believe that changes so great have taken place in the face of the earth, but one who diligently studies the rocks is impressed more with its instability and change than with its stability. He soon learns that change has been the rule rather than the exception—that the rocky crust of the earth, which is so frequently referred to as "everlasting," is not everlasting in the sense of unchangeable. The earth's crust has been and doubtless is to-day like thin ice that bends under the skater's weight but seldom breaks, and a depression in one place gives rise to an elevation in another. Depressions in the crust of the earth, if they were at all profound, have led to the invasion of the sea, and elevation has caused the formation of dry land and possibly mountains.

The shale over which the traveler is passing is known in most of western Colorado and Utah as the Mancos shale, but toward the east the middle part of the shale changes to limy shale and then to limestone (Niobrara), and where this limestone is found the shale underlying it is generally called the Benton shale. That the rocks which form the large ridge on the left are coal-bearing is shown by old prospects and mine dumps that at many places scar the slopes. The first old mine to attract attention may be seen on the left just before the train passes milepost 370. This mine was near the top of the ridge, and the coal was lowered to the valley by a long inclined tramway, but Nature is fast removing the scars made by man, and they will soon not be noticeable. The first active operation to be seen is the Garfield (Vulcan) mine, opposite milepost 371, which is on a coal bed 14 feet thick. Coal from this mine also is lowered to track level over an inclined tramway, but this tramway is comparatively short. Farther along the mountain side the traveler may see smoke escaping from an opening nearly on the same level as the mouth of the Garfield mine. This smoke comes from a fire in the mine that

has been burning for several years. Such fires may be started in many ways, but this particular fire is supposed to have started spontaneously in broken coal. Coal of comparatively low rank, such as that mined at Vulcan, is subject to spontaneous ignition, especially when crushed and undergoing alternate wetting and drying, by which the carbon of the coal is oxidized or combined with the oxygen of the air or the water so rapidly as to start a fire. In the old Wheeler mine, which was opened years ago in the mountain point on the north side of the valley, just beyond the village of Newcastle, it was found impossible to prevent the coal from taking fire, and many years ago, after repeated and unsuccessful attempts were made to extinguish it, the mine was abandoned, and the coal is still on fire. Spontaneous ignition of coal has occurred not only in mines but on the outcrop of coal beds of rather low rank, and these fires have burned as long as air was available, making the adjacent rocks bright red and, where the heat was especially intense, melting them to slag or clinker.

Newcastle.

Elevation 5,562 feet.
Population 447.
Denver 373 miles.

The railroad swings to the right along the banks of Colorado River and enters Newcastle. This place is well known as a coal-mining center and is one of the points for reaching the great hunting ground of the White River Plateau to the north. It was to Newcastle that Theodore Roosevelt came in 1904, while he was President of the United States, on one of his famous hunting expeditions. From the station may be seen the bottom layers of the Mesaverde formation in the hills immediately back of the village, and on the north (right) and ahead may still be seen the scars on the mountain side and the dump of the old Wheeler mine that was abandoned because of fire. The red color, due to burning, and possibly the smoke of the fire may be seen from the train. The Mesaverde is one of the greatest coal-bearing formations in the world. In the end of the Grand Hogback, on the right (see Pl. LXII, *A*), the aggregate thickness of coal in beds over 4 feet thick is about 109 feet. One of these beds—the Wheeler—is 40 feet thick, and several others are more than 10 feet thick.[43] At the time these coal beds were formed

[43] The coal-bearing rocks (Mesaverde formation) dip toward the west under the overlying rocks and then reappear between DeBeque and Palisade. These two areas of sandstone constitute the edges or rims of a great structural trough known as the Uinta Basin. A section across the trough is shown in figure 37. This basin forms one of the great reserves of coal in the Rocky Mountain region. It extends from Crested Butte in Gunnison County nearly to the Wasatch Mountains in Utah and is estimated to contain 160 billion tons of coal. The coal is mined in the Crested Butte district, at Newcastle and for several miles to the south, at Cameo and Palisade, at Thompson, Utah, and at Sunnyside and Castlegate, near the west end of the field. Coal is not mined in other parts of the basin either because the beds

the climate in this region was very different from that which prevails there to-day, as is shown by the kind of plants which grew at that time and furnished the material for the beds of coal. Palms then grew here luxuriantly, and many fragments of impressions of palm leaves have been found in the rocks that are associated with the coal. Plate LXII, *B*, shows an usually fine specimen found by the miners at Newcastle.

From Newcastle the trains of the Colorado Midland formerly ran to Grand Junction over the tracks of the Denver & Rio Grande Western. On account of this double use the roadbed between these points is treated as a distinct unit, and the mileposts do not conform to the general scheme of numbering consecutively from Denver but are independent, beginning at Newcastle and ending at Grand Junction.

About 1½ miles below Newcastle the traveler passes out of the Mesaverde formation and into the overlying Wasatch. This formation is of Tertiary age and is the first rock as young as Tertiary that the traveler has seen since he left the vicinity of Denver and Palmer Lake. It is characterized generally by coarse conglomerate and in places is composed of boulders many inches or even several feet in diameter. It is reddish or pinkish in color, or it is made up of bands of red alternating with bands of white or light green. It was not formed immediately after the Mesaverde, on which it rests here, but after the Mesaverde had been laid down, consolidated, raised above drainage level, and remained a land surface for a long time. At last the mountains were partly uplifted and great lakes were formed, and into these lakes boulders worn from the older rocks, as well as fine material, such as clay and sand, were washed, and the whole mass was finally consolidated into rock. The time which has elapsed since it was deposited and the pressure of the overlying rocks have not been sufficient, however, to make it very hard; it is much less coherent than the Mesaverde and consequently gives a greater width of valley than the older rock. The Wasatch beds near the outcrop of the Mesaverde dip steeply to the southwest, or into the great Uinta Basin, but at a greater distance from the hogback the beds flatten and become nearly level as they approach the middle of the basin. (See fig. 37, p. 148.) From Newcastle to Rifle the most prominent surface features on the right are the sharp conical hills of the Wasatch formation, in which the beds apparently stand on edge.

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are not accessible by railroad or because the coal is so low in rank that it could not be sold in competition with the coal already on the market.

The quality of the coal differs greatly in the different parts of the basin. The highest rank — anthracite — is found near Crested Butte, and the lowest rank—subbituminous coal—at points on the upturned rim. Coke is manufactured south of Glenwood Springs, Colo., and at Sunnyside, Utah.

The soft Tertiary and Cretaceous formations have been eroded very rapidly, and vast quantities of clay, gravel, and sand have been washed into the basin-like valley below the narrow canyon which the river has cut through the Grand Hogback. This loose material once filled the valley to a considerable depth, and the streams then removed part of it, leaving the remainder as great sloping terraces, which come down from the sides of the valley and would meet in the middle were it not for the trench which the river has cut. The presence of this fine material has given to one of the villages the appropriate name of Silt. On the old maps of this region this broad valley was called Cactus Valley, on account of the barrenness of the region and the presence of many forms of cacti. To-day the parts on which water has been taken bear little resemblance to a cactus valley, but the unreclaimed part is extremely barren. Here for the first time on this journey the traveler is coming into the real semiarid region, where precipitation is so slight that crops can not be raised without irrigation and where the unreclaimed tracts are either barren of vegetation or have the kind that is characteristic of the more nearly desert regions. On the south (left) the traveler may see the east front of Battlement Mesa, which is capped by a layer of basalt that has preserved the even surface over which it flowed as lava. Its east front, which is seamed and scarred, presenting a very rugged face, is one of the highest points in the vicinity, having an altitude of over 10,000 feet. The even surface upon which this flood of lava was poured is probably a part of the peneplain of which the White River Plateau is another remnant. Those who have made no study of geology may think that all plateaus are formed by the uplift of parts of the country to a greater altitude than that of the surrounding regions—in other words, that they are on anticlines or upfolds of the rocks, but this is not uniformly true. The White River Plateau is on such an upfold, but Battlement Mesa is in a downfold, and generally upfolds and downfolds have no necessary connection with the formation and preservation of plateaus.

Silt.
Elevation 5,441 feet.
Population 379.
Denver 380 miles.

Rifle, on Colorado River at the mouth of Rifle Creek, although not a large town, is one of the most important points on the railroad. The irrigated land along the river near Rifle yields abundant crops, but they are somewhat different from those that are raised about Glenwood Springs, for the land here stands at a lower altitude and the summer temperature is consequently higher. Potatoes and grains are not large crops about Rifle; sugar beets, alfalfa, and fruits are more common. From Rifle a stage line, 42 miles long, leads northward to Meeker, the largest town in the irrigated valley

Rifle.
Elevation 5,310 feet.
Population 885.
Denver 387 miles.

of White River and a noted outfitting point for hunters of big game. This road continues northward from Meeker to Craig, the present terminus of the Denver & Salt Lake Railroad ("Moffat road"). This part of Colorado has long been noted for the raising of horses and cattle, and for many years Rifle was the shipping point from which train after train of fine range cattle went to the eastern markets. The dry-land farmer has materially cut down the extent of the open range, so that the herds have been greatly reduced in number and size, and many of the cattle that are now raised reach the market by other routes, so that Rifle is no longer preeminently a cattle-shipping point.

Opposite Rifle is a marked terrace about 400 feet high, which forms a sharp boundary to the irrigated part of the valley. Like all the terraces so far seen, this one is doubtless a remnant of the old floor of the valley—a floor formed by the river when it was flowing some 400 feet higher than it does to-day, or when the surface of the land was that much nearer sea level than it is now. Remnants of what appears to be this same high terrace may be seen almost continuously below Rifle for a distance of 25 or 30 miles.

Beyond Rifle the great, broad swell of Battlement Mesa is the most conspicuous feature on the south side of the valley, but the reason for its name does not become apparent to the traveler until he has reached a point farther down the valley. As seen near Rifle Battlement Mesa is a great rounded mass in which very few ledges of rock crop out at the surface. It also bears very few trees, but parts of it, as well as of Grand Mesa, farther south, are covered with a thick growth of timber, and these two mesas constitute the Battlement National Forest. As the principal industry in this region is stock-raising one of the important features of the administration of this forest is the treatment of the "range" and the adjustment of grazing permits. For the information of those who wish to learn more about the administration of the national forests and the Government's method of dealing with grazing privileges, Smith Riley, district forester, has given a brief description in the footnote.[44]

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[44] "The barren piñon and brush covered foothills seen from the train between Rifle and Grand Junction give the traveler no idea of the fertile interior valleys and table-lands that comprise the Battlement National Forest—the largest grazing forest in the State of Colorado.

The forest proper, which lies somewhat remote from the railroad and covers an area of 677,340 acres, comprises two great table-lands known as Grand Mesa and Battlement Mesa. Fully 50 per cent of the area of the Battlement Forest is covered with timber. Wild grasses and weeds, which grow in abundance in open parks and in the less densely wooded parts of the forest, furnish excellent summer pasture. The foothills between

When Battlement Mesa is first seen from the railroad, near Rifle, no hard rock can be discerned on its surface, but near the village of Rulison small streams that come down from the mesa have made sharp cuts through the terrace on the opposite side of the river and have deposited at the foot of the terrace a great quantity of boulders in the form of alluvial cones. These boulders are composed of basalt, a dark rock that is very unlike any others which are seen in this vicinity. This basalt was once molten lava that was poured out over the even surface and now caps the mesa and protects its from erosion. Battle-

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the national forest and the valleys also provide valuable winter range, and the irrigated bottoms along the streams are admirably adapted to raising hay and to the winter feeding of stock. Such, in brief, is the character of the lands that furnish pasturage for more than 43,000 cattle and horses every year.

The natural grazing advantages of this part of Colorado attracted cattlemen long ago and led to the first development of the country. Those were days without laws or regulations, when the more powerful cattle owners had everything their own way, "running" as many cattle and sheep as they wished, rapidly overgrazing the accessible tracts and getting little or no benefit from the others. This "open-range" system, as it was called, resulted in the gradual accumulation of more live stock than the country could properly maintain, and during unfavorable seasons it produced severe losses.

In those early days the market was very unstable. Prices were less than half those of the present day, and there was a great deal of animosity between cattlemen and sheepmen. So strong was this animosity that between 1890 and 1892 several encounters occurred in which at least one man was killed and thousands of sheep were wantonly butchered or driven over precipices. Ultimately the cattlemen proved to be the stronger and drove the sheepmen from the range.

By this time the territory then in use had become overgrazed, the range depleted, and the water-supply contaminated and diminished. The struggle therefore took on a new phase—it became one for the control of range and water. Homesteads and water holes were taken up in such a way as to control large areas, some homesteaders controlling as many as 10 sections of grazing land.

After this struggle for supremacy the fruit industry was started and ultimately took possession of much of the fertile valley lands in and adjacent to the forest. For a time this new industry flourished, and the value of land increased to a point that prohibited its acquisition for grazing. The fruit industry in turn had its drawbacks, and now many of the orchards are being turned into fields of alfalfa. To dispose of this crop properly live stock is necessary, so there is now a revival of the cattle business.

Since the Battlement National Forest was established, in 1892, the grazing industry of this region has been reduced to a science. Range privileges have been equitably distributed by the Government on the basis of the bona fide development of permanent homes. Control of the range by rule of might has disappeared, overgrazing has been stopped, and the forest ranges are now used without injury to them. Most important of all, the live-stock business has been placed on a secure and profitable basis, and stockmen have come to look upon the Forest Service as their friend.

One of the first considerations in the proper administration of a grazing for-

ment Mesa was so named because of the fancied resemblance of its north front to the walls of some old castle, but the traveler can not see these rugged points until he has passed the east end of the mesa.

Beyond Rifle the most conspicuous features on the north (right) side of the valley are the great white cliffs of Mount Logan. When the traveler first sees them, near Rifle, they are in the distance, but as he goes westward he approaches them, and before the train has covered many miles it is running at their bases. Many of the maroon beds of the Wasatch, which came in so prominently on the west side of the Grand Hogback west of Newcastle, have passed below the level of the river; only a few hundred feet remains in sight to form a red-

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est is the establishment of "grazing periods" consistent with the protection of the forage plants. Under the supervision of the Forest Service the periods for grazing have been so adjusted that the cattle are not allowed on the range until the grass and soil are ready. This permits the full utilization of the forage without overgrazing or denudation. A careful study is also made of the "carrying capacity" of each individual range—that is, of the ability of a given tract to sustain stock in good condition without deterioration of the forage.

The construction and maintenance of drift fences (see Pl. LXIV, *B*) for properly handling stock on the range and of pastures for gathering stock and for weaning calves; the establishment of salt grounds, for salt is as necessary for beasts as for man; the construction of wagon roads and trails to open up new and unused parts of the range; and the improvement of springs and water holes—all this work and much of other kinds that have a vital bearing on the grazing industry has been done by the Forest Service in cooperation with the stockmen.

All grazing privileges in national forests, except for 10 head or less of milch cows or work horses, are granted under a formal permit that can be procured on application to the Forest Supervisor, though each year, with the increasing demand for range, the equitable allotment of these privileges is becoming more difficult. In its grazing policy the Forest Service takes the position that it would rather help the small man to make a living than the big man to make a profit. The development of local ranges and the production of winter feed is therefore encouraged, and within certain limits grazing privileges are granted to new settlers, even to the extent of reducing the privileges of those who have been "running" a large number of cattle. On the other hand, the so-called "vested rights" of the large owner are respected and his privileges maintained except where the small owner is being unduly crowded or denied consideration. Maximum limits as to the number of cattle and horses that may be "run" on the forest by the owner have therefore been established in order to prevent monopoly. The small stockman is also safeguarded by a "protective limit," which is the number of cattle the settler must have in order to make a living on his property. The small man is thus able to build up his holdings to this limit, and stockmen who claim larger privileges are assured that they will not be reduced unreasonably by the demands of the small man.

As the live stock that is grazed on the national forests furnishes a considerable part of the meat supply of the country, the Forest Service feels that it should promote the use of our grazing resources as fully as the proper care and protection of the forests and the water supply may permit.

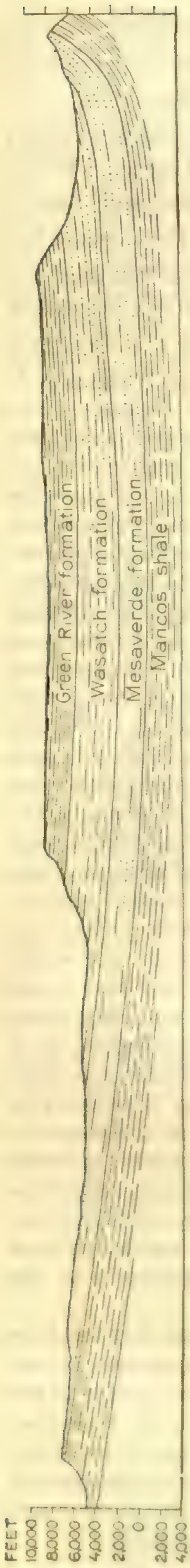


FIGURE 37.—Section across Uinta Basin from Newcastle (on the right) to Palisade (on the left).

dish band about the foot of the white cliffs. The relation of these beds to the Uinta Basin is shown in figure 37.

In the vicinity of Rulison the cliffs are very conspicuous, and from Rulison to Grand Valley the train runs practically at their feet. These cliffs, which tower to a height of 3,500 feet above the railroad, are but the points of long spurs which far back from the river unite in a broad, unbroken plateau. The upper part of the cliffs is composed of white shale and sandstone known to geologists as the Green River formation. These rocks, although originally dark, weather uniformly to a dull white. The base of the cliffs is made up of the maroon shale of the Wasatch formation, which is exposed at several places between Grand Valley and Salt Lake City. As shown in Plate LXIII, the Green River formation makes prominent cliffs on the north side of the valley and occurs also in the high parts of Battlement Mesa, on the south. Its presence is generally indicated by its white color, which shows wherever the cover of brush and trees has been removed. In such places it is soon cut into castellated forms.

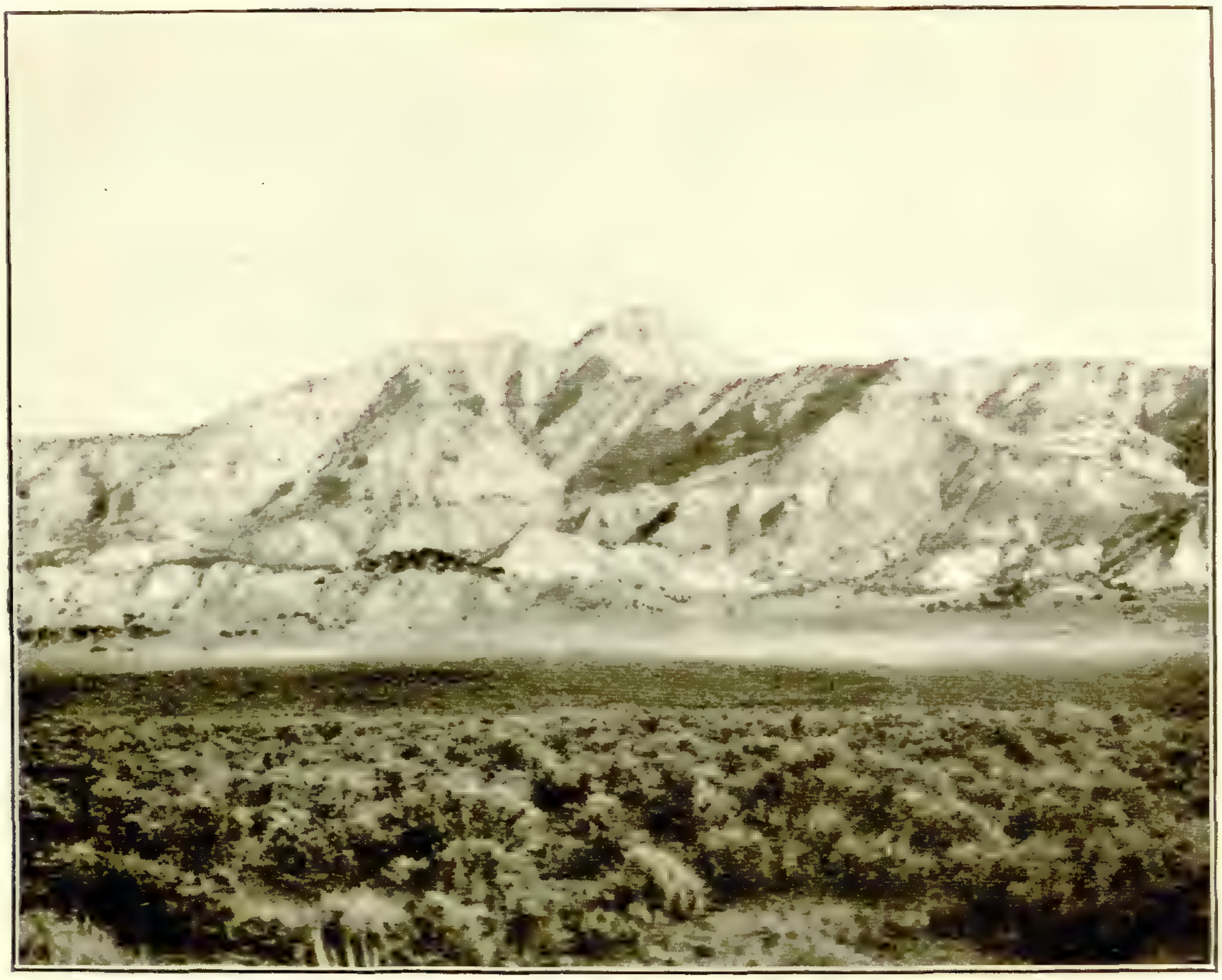
Most of the lower part of the valley is irrigated and produces good crops and considerable fruit. A sloping terrace on the south side of the river, opposite the village of Grand Valley, is irrigated by streams that come down from the higher parts of Battlement Mesa, and the scene here is a pretty picture of rural peace and prosperity. The principal scenic feature is the great white cliff (Pl. LXIII) immediately back of the village. All except about 600 feet at the base of this cliff is composed of shale of the Green River formation, which, aside from its striking color, is notable because it contains a large amount of organic material, mostly remains of plants, from which oil may be obtained by destructive distillation. Oil has not yet been produced commercially from this shale, but it probably will be when crude oil from wells becomes scarcer and the demand for gasoline is greater than it is to-day. This shale has been

Grand Valley.

Elevation 5,104 feet.
Population 257.
Denver 404 miles.

GRAND VALLEY CLIFFS.

The picturesque cliff back (north) of Grand Valley, as seen from the south side of Colorado River. This country is a vast plateau in which Colorado River has carved its valley to a depth of 3,000 to 4,000 feet. The cliffs are the cut edges of the beds that form the plateau. The lowest beds are Wasatch, but those near the top of the plateau are oil shale of the Green River formation. Photograph furnished by the Denver & Rio Grande Western Railroad.



A. BARE HILLS OPPOSITE DE BEQUE.

Although these hills are in the extreme west end of the Battlement National Forest they bear very little timber or in fact vegetation of any kind. They are composed of the same kind of material as that shown in Plate LXV, *A*. Photograph by the U. S. Forest Service.

B. STOCK FENCE IN A NATIONAL FOREST.

A drift fence for controlling the pasturage of stock in the Battlement National Forest. To one accustomed to a humid climate the vegetation on this land does not appear promising, but the cattle can find good pasture between the bunches of sage. Photograph by the U. S. Forest Service.

studied, tested, and mapped by Dean E. Winchester, of the United States Geological Survey, who describes it below.[45] A moderate estimate, made by him, of the quantity of oil that may be obtained from the Green River formation in Colorado alone is 40,000,000,000 barrels.

The oil shale is within view from the railroad for only a short distance in Colorado, near Grand Valley, and is not seen again by the traveler until he reaches Colton, Utah, but the two areas are

[45] Before petroleum was discovered in Pennsylvania, in 1859, the Mormons distilled it, in an experimental way, from shale of the Green River formation near Juab, Utah, where the ruins of their old still may yet be seen. Experiments in other parts of northeastern Utah and northwestern Colorado have confirmed the results obtained at Juab. For many years oil has been distilled from similar shale in Scotland, where large plants have been erected for this purpose, but the supply of crude petroleum in this country has been so great that no one has been willing to invest capital in such an enterprise. The growing demand for gasoline, however, has made it imperative to seek further supplies of oil, so the United States Geological Survey has been testing the so-called oil shale of the Green River formation to find how many gallons of oil it will yield per ton and mapping its geographic distribution so as to be able to make some estimate of the total quantity of oil that may be obtained from it. A conservative calculation of the oil content of the shale in Colorado shows that it will yield at least 40,000,000,000 barrels of crude oil. The yield of gasoline would be one-tenth as much, and with a little added expense 300,000,000 tons of ammonium sulphate would be obtained as a by-product. The sulphate is an excellent fertilizer and would be highly valuable to the farmers in this and adjacent regions.

The Green River formation, which is so well exposed in the great white cliffs at Grand Valley, consists predominantly of shale, but in places it includes beds of sandstone, oolite, and conglomerate. The general white color of the weathered outcrops is varied near the top of the big cliffs by hard bluish beds, which when freshly broken are dark brown or black and give off an odor of petroleum. This hard, dark shale is destined to become a valuable source of crude oil and its refined products, such as gasoline and kerosene, as well as of nitrogen compounds. Good oil shale is tough and remarkably flexible. Thin splinters will burn and give off an asphaltic odor when ignited with a match. Oil shale contains a vast amount of organic matter, largely vegetal, which appears to be the source of the crude oil that may be produced from it by destructive distillation.

The average oil shale mined in Scotland will yield about 25 gallons of crude oil to the ton, but there is an abundance of shale in Colorado and Utah that will yield a barrel (42 gallons) to the ton. The crude oil, when refined by ordinary processes, will yield from 10 to 15 per cent of gasoline.

Experiments are now in progress both in the laboratories of the United States Bureau of Mines and in many private establishments to devise a method of retort treatment that will most successfully produce a distillate that can readily be refined into standard products at a profit. Such a method will no doubt be found, and this region in northwestern Colorado will probably be the scene of a great industry in the production of artificial petroleum by the distillation of these deposits of oil shale.

connected north of the railroad by an almost unbroken outcrop, and shale of sufficient thickness and richness to warrant mining is supposed to underlie an area of at least 5,000 square miles in the Uinta Basin of northwestern Colorado and northeastern Utah.

The features below the town of Grand Valley are much the same as those above it. The same white cliffs, with the maroon band about the base, rise above the railroad on the north, and the broad swell of Battlement Mesa rises on the south. Between lies the open valley, with its band of trees fringing the river and its patches of farm land where the surface is sufficiently level for irrigation. In midsummer the valley displays beautiful shades of green, but in autumn, after the early frosts have touched the cottonwood trees along the river and the aspens on the slopes above, it bears a beautiful mantle of green and gold.

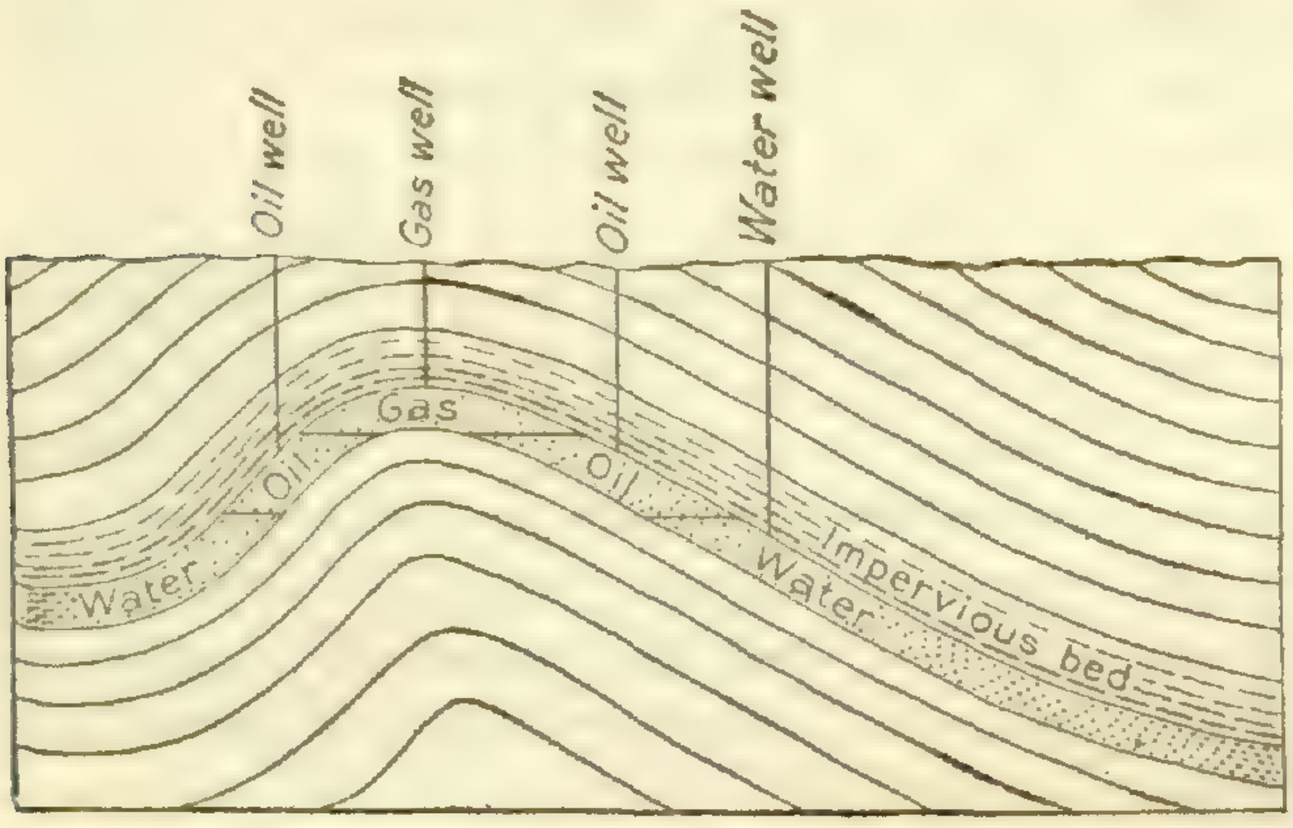


FIGURE 38.—Relation of oil, gas, and water to an anticline. In a porous sandstone gas may be forced to the top of the arch, oil will come next, and water will lie in the lower part.

The hills across the valley, although they lie within the Battlement Forest, are composed of the red and green shale and sandstone of the Wasatch formation and are almost devoid of vegetation. (See Pl. LXIV, *A*.)

After being crowded close to the river by the high bluffs of the maroon shale and sandstone, the railroad suddenly emerges into the broad valley of Roan Creek at the little village of

De Beque.

Elevation 4,945 feet.
Population 292.
Denver 417 miles.

De Beque, which is flanked on the north by the high turrets, towers, and minarets of the White Cliffs. As Roan Creek heads on the high plateau it contains a never-failing supply of water, which is used over and over again in irrigating the level land within its valley. The pasture on the plateau is excellent, so that the principal industry in and around De Beque is stock raising.

West of the river there is a slight arch in the rocks on which a number of wells have been drilled in search of oil. Some of these wells have found small quantities of oil, but most of them have been "dry holes"—that is, holes that yield little or no oil. The slight arch in the rocks is regarded as favorable for the accumulation of oil, for oil and gas are generally associated with water in the rocks, and as they are lighter than water they are forced up into the high places or arches, as shown in figure 38, but in the region about De Beque there seems to be little or no oil in the rocks to accumulate.

GEOLOGIC AND TOPOGRAPHIC MAP
OF THE
RIO GRANDE ROUTE
From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
GEORGE OTIS SMITH, DIRECTOR

DAVID WHITE, Chief Geologist — C. H. BIRDSEYE, Chief Topographic Engineer
M. R. CAMPBELL, Geologist — A. C. ROBERTS, Topographer

1922

EXPLANATION

		Age	Thickness in feet
E	White shale and sandstone (Green River formation)	Tertiary (*Eocene*)	2,600
F	Red shale, sandstone, and conglomerate (Wasatch formation)	Tertiary (*Eocene*)	3,400
H	Sandstone, shale, and coal beds (Mesaverde formation)	Upper Cretaceous	5,000
J	Dark marine shale (Mancos shale)	Upper Cretaceous	5,000
M	Brown sandstone (Dakota sandstone)	Upper Cretaceous	100±
N	Variegated shale and sandstone (Gunnison formation)	Cretaceous (?) and Jurassic	250
P	Brick-red sandstone	Triassic	1,200±
R	Red sandstone and shale (Maroon formation)	Carboniferous (*Pennsylvanian*)	1,900
S	Red sandstone, conglomerate, and shale (Weber formation)	Carboniferous (*Pennsylvanian*)	4,000
U	Blue limestone (Leadville limestone, Ouray limestone)	Carboniferous (*Mississippian*) and Devonian	150
V	Quartzite, shale, and some limestone	Cambrian	490
X	Granite	Pre-Cambrian	
Y	Lava flows (basalt)	Tertiary	

Fault

The limestone of lower Carboniferous (Mississippian) and Devonian age is called Ouray limestone, but Ouray and Leadville are approximately the same

A short distance west of the station at De Beque the railroad crosses Roan Creek, and beyond for some distance it runs through a rolling country, most of which is irrigated and contains good farms. The river bottom on the east (left), which occasionally may be seen from the train, is also largely under cultivation, and beyond it the highland rises, terrace above terrace, up to the crest of Battlement Mesa.

The intricate lines of sculpture that are carved by the rains in the soft shale or clay where it is not protected by a cover of vegetation or of broken rock are well shown in some badland buttes composed of maroon shale and clay of the Wasatch formation, a little more than 2 miles west of De Beque. (See Pl. LXV, *A*.) If the light is just right to bring out the minute lines the entire surface of the buttes will appear to be made up of a series of rill marks that resemble the delicate fretwork of an artist. (See route map, sheet 6, p. 182.)

The rocks across which the traveler has been passing since he left Newcastle are bent into a great downfold or troughlike depression (syncline) whose east rim is composed of the coal-bearing sandstone (Mesaverde) that forms the Grand Hogback. Figure 37 (p. 148) represents the section across this trough as it is exposed by Colorado River. The other rim of the trough is crossed by the railroad between De Beque and Palisade, and through this rim the river has cut a deep and narrow canyon very different from the gap through the hogback at Newcastle. It is here called Palisade Canyon.[46] As the rocks are the same at both places the explanation of the difference in the appearance of the gaps cut by the river must be sought in the difference in the attitude of the beds, or, in other words, in the amount of their dip. At Newcastle the thick bed of sandstone dips steeply toward the west, and as it is underlain by softer rocks it weathers into a sharp ridge, which can be traced for 50 miles to the north and is known as the Grand Hogback. The dip of the beds on the other rim of the trough is very slight, generally not over 10°, and the river cuts through the rim for 16 miles in a canyon that increases in depth as it approaches the outer margin of the sandstone. Figure 37 (p. 148) represents the rocks as they would appear in a deep trench cut along the line of the railroad. Above the coal-bearing rocks lies the maroon Wasatch, and in the middle and overlying all the other beds, and consequently younger than the others, are the white beds of the Green River formation, but these do not appear near Palisade Canyon.

[46] So far as the writer is aware this canyon has been called by no name except "Hogback Canyon," which appears several times in the Hayden reports, printed about 1875. That name was never strictly appropriate, for the ridge of slightly dipping rocks across which the canyon is cut is not a typical hogback, and as the name has never become current it seems appropriate to give the canyon the name of Palisade Canyon, from the town of Palisade.

South of De Beque the railroad is built on a low terrace at some distance from the river, but near the entrance to Palisade Canyon, 4½ miles south of De Beque, halfway between mileposts 48 and 49, it reaches the river (on the left) in a shallow canyon cut into one of the thick beds of sandstone near the top of the coal-bearing Mesaverde formation. As the beds rise gradually downstream the canyon slowly increases in depth from its head to Palisade, where it ends. At Akin siding (milepost 51) the canyon walls are about 300 feet high, and they show well the alternate bands of resistant sandstone and soft, easily eroded shale. Here and there some of the beds of sandstone are thick and massive and form cliffs 40 or 50 feet high, but on the whole the alternation of shale and sandstone gives rise to sloping banded walls which have a sameness in appearance that soon becomes monotonous.

At Tunnel siding (milepost 55) the walls of the canyon have increased in height to 600 or 700 feet, but they have the same general character. A mile west of this siding the train passes through a tunnel which pierces a long spur (shaped in plan like a beaver's tail, hence the name Beavertail tunnel) that projects from the right wall of the canyon and then comes to a diversion dam which turns some of the water of Colorado River into a canal on the other side of the river. This canal is in sight throughout the length of the canyon below this point, and its effects may be noted in the crops and orchards on the high bench lands east of the river.

Milepost 57 marks the largest diversion project in the canyon, known as the Grand Valley or High Line project of the United States Reclamation Service, which is intended to furnish water for the irrigation of the high bench lands on the north side of the river from Palisade as far west as the western boundary of the State. The diversion dam, shown in Plate LXVI, is completed, and the canal is constructed as far west as Loma (see p. 153) and in the near future will be extended to the State line.[47]

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[47] The Grand Valley project of the United States Reclamation Service, usually spoken of as the High Line canal, provides for the irrigation of 45,000 acres of land in Mesa County, Colo., comprising, as shown in figure 39, a strip along the northern border of the valley above the old private canals from 2 to 6 miles wide and 40 miles long. The water is taken from Colorado River (formerly called Grand River) by a diversion dam (shown in Pl. LXVI) 8 miles above Palisade, into a main canal 65 miles in length, extending to a point 6 miles northwest of Mack. About 35,000 acres lies under the main canal and will be supplied by gravity, and 10,000 acres lies above the level of the main canal and will be supplied by electrically operated pumping plants.

The most interesting engineering works in this project are the diversion dam and the first 6 miles of main canal, which are in the canyon of Colorado River. The dam, which is unique in American engineering, consists of a concrete weir, 546.5 feet in

A. NATURE'S LACELIKE SCULPTURE.

Fine sculpturing by the rain on a butte of red and white clay on the right of the track 2 miles south of De Beque. Every part of the surface is thoroughly drained, and each rivulet has carved for itself a distinct channel. Photograph by Marius R. Campbell.

B. PALISADE CANYON AT CAMEO.

The walls of the canyon back of Cameo are about 1,500 feet high and are composed of sandstone and shale of the Mesaverde formation. These weather into castle-like cliffs and slopes, as shown in the view. Photograph by Marius R. Campbell.

HIGH LINE DIVERSION DAM IN PALISADE CANYON.

This great structure was thrown across Colorado River in the heart of Palisade Canyon by the United States Reclamation Service in order to divert water for the irrigation of 45,000 acres of bench land west of Grand Junction. The estimated cost of the completed project is $4,600,000. Already more than $3,700,000 has been expended, and water is now available for the irrigation of 38,000 acres. Photograph by U. S. Reclamation Service.

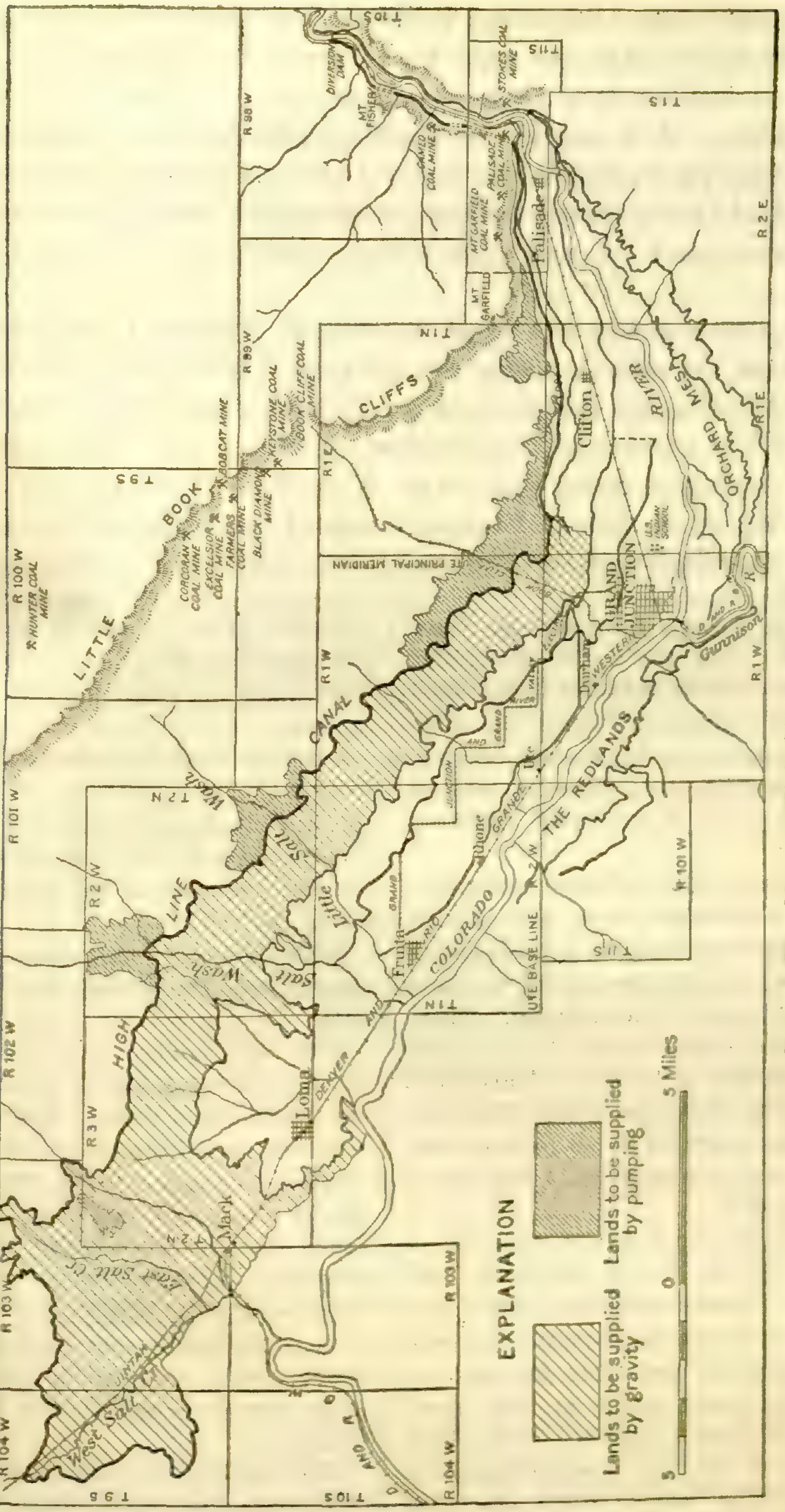

FIGURE 39.—Map of High Line reclamation project.

length, resting on a gravel foundation and provided with seven steel roller crests for regulating the height of backwater. Six of these roller crests are 70 feet long and 10 feet 3 inches in height, and the seventh is 60 feet long and 15 feet 4 inches in height.

During the period of low water, when practically the entire flow of the river will be diverted, these roller

The great High Line canal is crossed by the railroad a short distance below the dam and may be followed by the eye on the right until it is hidden in a tunnel that carries it through a projecting rocky point. It is carried as high as possible, and though it has descent enough to enable the water to flow readily, it is soon above the level of the railroad and can be identified only by the regularity of its banks and the new rock dumps that mark the portals of its tunnels.

Half a mile below the High Line dam Plateau Creek enters the river from the side opposite the railroad. This creek heads on the mesa far to the east and flows in a narrow valley between Battlement Mesa on the north and Grand Mesa on the south. The main automobile highway down the river is carried over the low plateau east of the river, but at Plateau Creek it descends to the river and for the remainder of the distance to the lower end of the canyon it

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crests will rest on the weir and force the water into the canal headgates, but at times of flood they will be rolled up on the piers, allowing the high water to pass over the dam in order to avoid flooding the adjacent track of the Denver & Rio Grande Western Railroad.

The first 6 miles of main canal parallels the railroad track, and in narrow parts of the canyon in this stretch three tunnels have been built to avoid interference with the railroad. These tunnels are, respectively, 3,723, 1,655, and 7,292 feet in length and are lined throughout with concrete. The first two tunnels are 14 by 16 feet in cross section, and the third is 11 feet by 11 feet 6 inches.

The main canal has a capacity of 1,425 cubic feet per second for the first 5 miles. About half this water will be used for developing power and will be returned to the river through the proposed power plant at the upper portal of tunnel No. 3. This plant, which has not yet been constructed, will develop about 2,000 electrical horsepower, which will be used in operating pumps to supply water to the lands that lie above the main canal.

The last 60 miles of the main canal consists of open ditch, involving about 2,600,000 cubic yards of excavation, and numerous flumes, siphons, and culverts, made to cross natural drainage courses.

Laterals will be constructed to deliver water to each farm on the project, and drainage works will be built as needed to remove surplus water and prevent the rise of the ground-water level.

Water for seasoning the works was turned into the main canal in June, 1915.

The soils under the project are of three general types — reddish sand, sandy loam, and adobe. The red soil is deep and well drained and is specially adapted to fruit culture, though practically all crops do well in it; the sandy loam is an alluvial soil and is adapted to growing certain varieties of fruit as well as alfalfa, cereals, potatoes, sugar beets, and vegetables; the adobe soil is adapted to growing alfalfa, cereals, sugar beets, and vegetables.

The cost of the works is advanced by the Government under the terms of the Reclamation Act, which provides that the actual cost shall be repaid by the landowners in 20 years without interest, and that they shall pay the cost of operation and maintenance.

follows the opposite bank. The walls of the canyon here are about 1,000 feet high and are therefore very imposing, especially where the beds of sandstone are particularly thick or resistant.

Cameo.
Elevation 4,774 feet.
Denver 433 miles.

At the little coal-mining town of Cameo the canyon attains its maximum depth, about 1,500 feet. Its sides generally present the appearance of gigantic walls of masonry, the beds of sandstone forming the courses and the soft shale filling in between them like the mortar in an artificial wall. On the projecting points between the main canyon and the canyons of the tributaries the sandstone seems to form most of the wall, as it stands in gigantic pyramids that tower far above the bottom of the gorge. The pyramid on the projecting point just north of Cameo is shown in Plate LXV, *B*.

Although the Mesaverde is the great Cretaceous coal-bearing formation in this region, it contains very few coal beds in Palisade Canyon. At Newcastle it contains more than 109 feet of coal in beds thick enough to work, but in Palisade Canyon it contains only two beds. The upper of these beds is mined at Cameo and is generally known as the Cameo coal bed. Mines may be seen just south of the station on both sides of the track. The coal from the mine on the left is brought across the river on a high trestle, which serves as a tipple for screening the coal and loading it into railroad cars. The coal mined here is of medium grade and satisfies the local demand, but it is not equal to that which is mined south of Newcastle, or in the Crested Butte region, on the east, or at Sunnyside and Castlegate in Utah, on the west. At the Cameo mine the coal bed has a thickness of 10 feet 11 inches, of which 9 feet 8 inches is clear coal.

About a mile below Cameo the High Line canal passes through the plateau by a long tunnel which brings it out on the high bench land west of Palisade.

Nearly 2 miles below Cameo the river makes a big curve to the right, and on the opposite side there is a low terrace not more than 150 feet high. This terrace has been built up by material brought down by a small creek that heads on Grand Mesa, to the east. This material is so abundant and so indestructible that it has crowded the river gradually against the opposite (west) side, so that the river has been forced to cut under a great cliff, several hundred feet in height. From the train the traveler may see that this terrace is composed almost entirely of boulders of a dark rock, which close examination would show to be basalt, or hardened lava. Grand Mesa, which here and there may be seen on the east (left) and which overtops all other features in this region, has been preserved almost entirely because it is protected by a cap of this basalt.

Below the terrace two small water-power plants have been constructed for pumping water to higher levels to irrigate land that

could not be reached by the existing gravity lines. One of these plants supplies enough water to irrigate 2,300 acres of land and the other enough to irrigate 6,000 acres. The canals and pumping plants which the traveler has seen in Palisade Canyon are more extensive than any that he has seen heretofore on this journey, and he may wonder why so much money has been spent to obtain the water of Colorado River, but when he has passed out of the mouth of the canyon and has seen the wonderful change that the water has made in the one-time desert plain he will no longer question the wisdom of the expenditure.

As the railroad makes a great bend to the west at the mouth of the canyon the traveler may notice some small coal mines that are operating on the lowest or Palisade coal bed. This coal bed, which ranges from 3 to 7 feet in thickness, overlies the sandstone that is regarded as forming the base of the Mesaverde formation. The coal bed and the sandstone are well exposed across the river, where a number of small mines have been opened to supply the local demand for fuel. Another small mine is also in operation just above the station at Palisade. The rocks here rise more rapidly than they do farther up in the canyon, and the lower slopes of the cliffs are composed of the marine shale (Mancos) that underlies the coal-bearing formation.

Near milepost 63 the canyon opens, and here begin the orchards of peaches, pears, apples, and other fruit that have made the town of Palisade famous. Its situation at the foot of the Book Cliffs protects it from late frosts in spring and from early frosts in autumn, so that almost every foot of the land is under irrigation and has been planted with fruit trees. (See Pl. LXVII.) Every year hundreds of cars of fruit are shipped from this place.

Palisade.
Elevation 4,739 feet.
Population 855.
Denver 487 miles.

Here begins the great southward-facing cliff which in the early days was named Book Cliffs because of the fancied resemblance of the sandstone cap and the curved shale slope below to the edge of a bound book. A typical view of the Little Book Cliffs as they appear back of Palisade is given in Plate LXVIII. The Book Cliffs begin at Palisade and stretch westward to Castlegate, Utah, a distance of about 190 miles. They everywhere form the southern rim of the great trough of rocks on the north known as the Uinta Basin. Just west of Palisade the cliffs are formed and protected by a few beds of sandstone at the top, below which the slope consists of shale (Mancos) that was deposited there before the Rocky Mountains were in existence, when the entire region was below the waters of the sea.

These shale slopes have been intricately sculptured by the rain, and the traveler has many opportunities to examine them, for they are

COLORADO RIVER VALLEY BELOW PALISADE.

Since the waters of Colorado River have been diverted in Palisade Canyon and carried out on the level land below, the valley has been developed into a paradise of orchards and well-tilled fields. Photograph furnished by the Denver & Rio Grande Western Railroad

LITTLE BOOK CLIFFS AT PALISADE.

The Little Book Cliffs at Palisade are capped by a hard bed of sandstone (base of Mesaverde formation), and the slopes of soft shale below are most intricately carved by rain and running water. These cliffs serve to protect from frost the acres and acres of orchards at their feet. Photograph by G. B. Richardson.

visible on the north from the train most of the way from Palisade to Castlegate. The appearance of these slopes, like that of most of the land forms in a semiarid climate, depends largely upon the light under which they are seen. When the light is strong and strikes squarely against the face of the cliffs the slopes are expressionless and dead. One slope is like another as they shimmer in the hot rays of the sun, but when the sun is low the shadows show every detail of the slopes, and thus revealed in black and white the surface of the cliffs looks as seamed and wrinkled as the face of an old man. Each slope is then full of individuality—it shows intricate and wonderful sculpture.

The valley that the railroad enters at Palisade is broad because the soft Mancos shale, in which it is carved, is about 3,000 feet thick, and its erosion has produced flat or rolling lands except where terraces have been cut by the streams into badlands or steep slopes. Although the shale contains considerable alkaline material, which is objectionable in farming, it makes in general some of the best farming land in western Colorado. Near the river it forms flat valley bottoms, as at the village of Clifton, but by proper underdraining even such flat lands may be made very productive. Orchards abound in this valley, and much fruit is shipped from Clifton. Before the water of Colorado River was diverted and carried onto this land it was a waste desert, inhabited only by jack rabbits and coyotes, but irrigation has transformed it into a fertile land, figuratively "flowing with milk and honey." Is it any wonder that millions of dollars have been spent in diverting water from Colorado River in the canyon above Palisade and in constructing great canals for delivering it to the thirsty land? But even after all our great irrigation works have been completed there will still be millions of acres of waste land, which could be converted into sites for homes of peace and plenty if water were available. The great problem of the future is to conserve all the water that is produced by the melting of snow in the high mountain regions, by holding it in storage reservoirs until it is needed, and then to distribute it to the desert land. Such work will require enormous sums of money, but it will in return supply homes to many thousands of people and bring immense wealth to the country.

Clifton.

Elevation 4,713 feet.
Population 855.*
Denver 443 miles.

General views of the valley may be obtained from places near Clifton. On the east tower the wooded slopes of Grand Mesa; on the south, far in the distance, may be caught glimpses of the gently swelling surface of the Uncompahgre Plateau—a surface composed of the massive sandstones which at some places underlie the Mancos shale and which everywhere overlie the granite that forms the basement upon which all this country is built.

The railroad traverses the flat land of the river bottom to the point where Colorado River is joined by Gunnison River, which heads in the high mountains near Marshall Pass and which is followed throughout most of its course by the narrow-gage line from Salida to Montrose and by the standard-gage line from Montrose to Grand Junction. At the junction of these roads stands Grand Junction, a division point on the railroad and the largest town in western Colorado. Grand Junction is the center of a vast irrigated district whose climate is favorable to the growth of almost all kinds of grain, as well as forage crops, sugar beets, garden truck, and fruit. It is particularly noted for its beet-sugar industry and for its fruit.

Grand Junction.

Elevation 4,583 feet.
Population 8,665.
Denver 450 miles.

The description of the country along the main line west of Grand Junction is continued on page 185.

NARROW-GAGE LINE FROM SALIDA TO MONTROSE.

The description of the country along the main line east of Salida ends on page 90.

The part of the Denver & Rio Grande Western Railroad that runs over Marshall Pass was a part of the main line built with a 3-foot gage in 1881, and because of its steep climb over the mountains and its tortuous course through the Black Canyon of the Gunnison it has not been changed from its original gage. To the traveler who has never ridden in a narrow-gage coach the name "baby railroad," which was given to this system in the early days, seems eminently proper; but after traveling over the mountains and turning and twisting through the narrow canyons he gains respect for the narrow-gage road, which in this part of the country was the pioneer of railroads and led to the development of the mineral resources and the agricultural wealth much earlier than if the road had been built standard gage. In Colorado, however, the day of the narrow-gage road seems to have nearly passed, and all such lines will probably be abandoned or changed to standard gage.

The country about Salida is well watered, and much hay and grain is grown for the herds of cattle that may be seen from the train. Some fruit is raised, but the altitude here is so great that only the more hardy varieties will ripen. On leaving the station the railroad runs southwestward, directly toward the great mountain wall that bounds the valley. (See sheet 3, p. 100.) It ascends the valley of South Arkansas River, in which no rock can be seen in place except at a distance until the train enters the mountains. The immediate valley is excavated in gravel and boulders, which may be

seen on the right in the cut edge of a well-developed terrace.[48] The top of this terrace, when seen from a high point, appears to be a part of what was once the floor of the valley. Remnants of a similar though higher terrace may be seen in the foothills on the left at a much greater elevation. (See Pl. XLIV, p. 90.)

The traveler is now near the high mountains, and he may look up on the left to lofty peaks on which the snow banks of the preceding winter linger well into the summer and on which a fleecy mantle falls during the first snowstorms of early autumn, or even occasionally during a cold midsummer storm. The commanding summits which may be seen from time to time are Ouray Peak (altitude, 13,955 feet), near Marshall Pass (altitude, 10,856 feet), and Mount Chipeta on the left, and a group of peaks known as Mount Shavano (altitude,

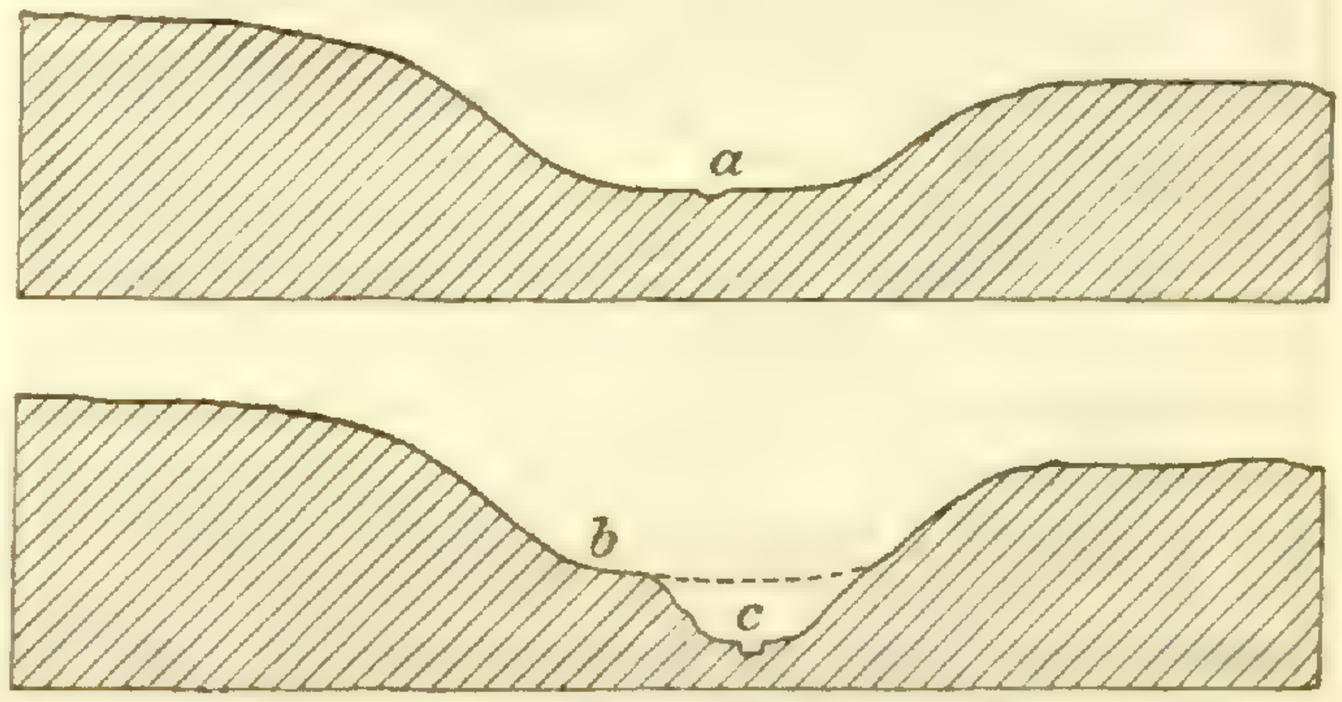

FIGURE 40.—Formation of a rock terrace.

[48] The mode of formation and hence the meaning of terraces is of great interest to the geologist who is attempting to unravel the history of the land. Terraces are mainly the work of water, either running, as in streams, or standing, as in a lake or ocean; but the present surface of Colorado has not been modified by the ocean and very little by lakes, so that most of the terraces here were formed by running water.

Streams may form terraces of two kinds, known as cut terraces and built terraces. A stream may flow against a bluff of solid rock and cut it away above a certain line and thus produce a flat which, when the stream has further excavated its valley, may be revealed as a terrace or bench. Such a terrace is represented in figure 40. A stream, *a*, has cut a valley in solid rock, represented by the diagonal-ruled lines. After the stream has formed a flood plain it begins to meander or swing from side to side across the flood plain. In the course of such a swing it may flow against the slope on the right and then, if the stream is accelerated by uplift, it will clean out its old valley and cut a trench (*c*) in its rock floor, leaving the part at *b* untouched. The part at *b* is then a rock terrace on the side of the valley and merely a remnant of the old valley formed when the stream was flowing at a higher level. Such terraces are called cut terraces and are rather rare.

The second kind of terrace is known as a built terrace because it is built of waste rock material by waves or running water. Most if not all of the terraces in a mountain region are built. A terrace is generally not built up directly by a stream but is the result of the filling or partial filling of the valley and of its partial excavation by the stream. If a mountain stream, such as the Arkansas, which is now able to carry along nearly all the sand and boulders swept into it by its tributaries, should be dammed by a flow of lava or other obstruction, it would be unable to carry its load of this material, which would be dropped in the pond above the obstruction. In time

14,179 feet) on the right. The lower slopes are more or less covered with timber, which becomes scanty as the height increases, until finally even the stunted balsams disappear (see Pl. XLV, *A*, p. 92) and at the summits there is nothing but wind-swept rock. The slopes vary in color according to the light, at times being rich red or bright yellow in the strong sunlight and at others deep purple or a steely blue. The color of the lower slopes depends largely on the vegetation, but that of the upper slopes depends on distance and light. In spring and summer the shrubs and trees present many shades of green and yellow, but they are most brilliant in September, when the first frost touches them and tinges them with red or gold.

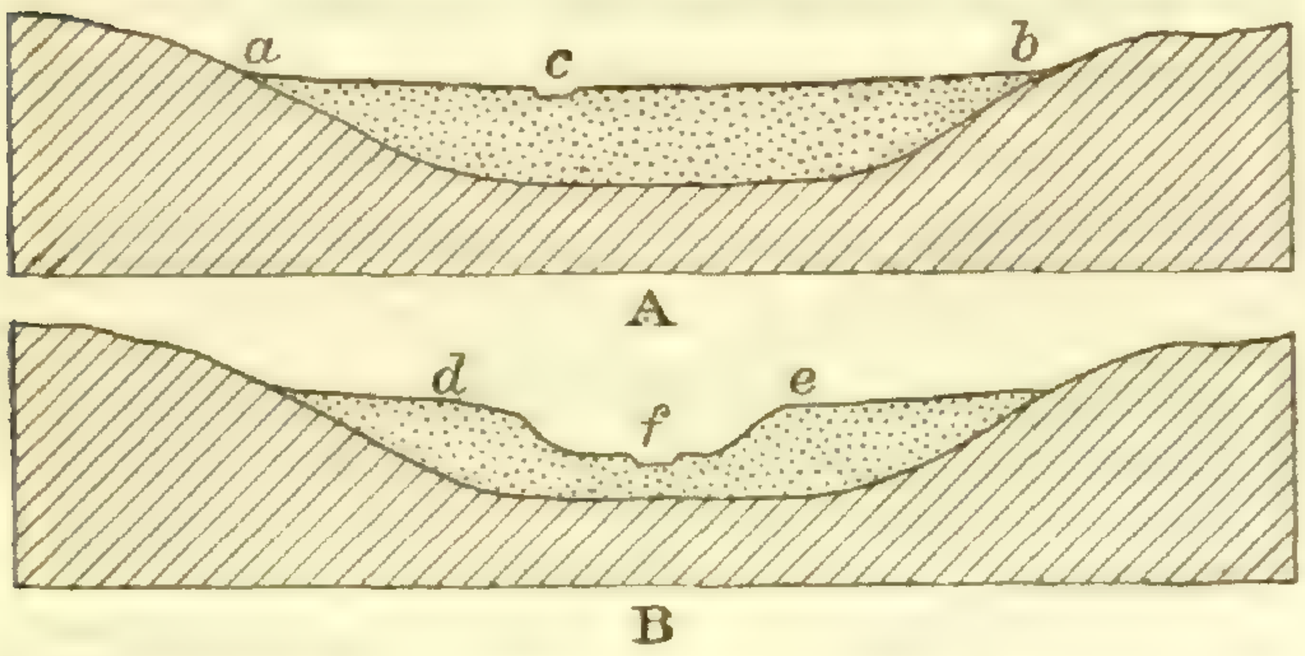

FIGURE 41.—Formation of a gravel terrace.

The railroad follows the valley up to the village of Poncha, where the road to Marshall Pass turns to the south (left), but a branch keeps straight ahead to the mining town of Monarch, 15 miles distant, where it ends. From Monarch the principal highway between Salida and the Gunnison Valley is an automobile road across the range.

Poncha.

Elevation 7,480 feet.

Population (including Poncha Springs) 323.

Denver 220 miles.

The Marshall Pass line turns to the south in a broad curve and begins to climb the range. For half a mile it cuts

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the material would fill this pond and form a plain that would stretch entirely across the valley. The result is shown by section A, in figure 41, in which the valley is represented as filled with gravel and sand, forming a plain *a-b*, over which the stream flows at *c*, far above bedrock. If the stream then succeeds in cutting through the dam of lava it quickly trenches the sand and gravel laid down in the pond, except the parts that lie at some distance back from the middle of the channel. The result is shown by section B, in figure 41, in which the stream has cut the trench *d-f-e*, leaving *d* and *e* as terraces on the sides of the valley, composed of sand and gravel which the water has deposited. Most of the terraces in the mountains have had such an origin, except that the ponding has generally been due not to lava flows but to the sinking of the crust of the earth, which would have the same effect as a lava flow. In some places it may have been due to a decrease in the volume of water flowing in the stream, and although at first thought this may not seem to be comparable to the lava flow in its effects, a careful study will show that the carrying power of a stream is directly affected by its volume and grade, so that if its volume or its grade is reduced its carrying power will be reduced—it will not be able to sweep along the boulders that it had before handled readily. A stream thus reduced in volume or grade silts up its bed, and if later its flow or grade is increased it cuts away all this material except the remnants that form terraces.

through ridges and spurs of gravel and boulders which constitute a part of the high terrace already mentioned. Near milepost 222 it enters the canyon which Poncha Creek has cut in the hard rocks that compose the mountains.

A quarter of a mile above milepost 223 the railroad swings to the left in a broad curve around a mass of loose material which has been swept down from a small gulch on the right, and almost immediately after swinging back into its normal position it has to make another curve in order to pass a second mass of similar loose material. Such masses, if fairly flat, are known as alluvial fans, but if steep they are called alluvial cones. The fans in Poncha Canyon are shown in the accompanying diagram (fig. 42). On the first fan the radial lines occupied by the streams at different times can easily be seen from the train, as they are marked by straight depressions and by ridges of boulders and angular pieces of broken rock which have been swept down by the stream.

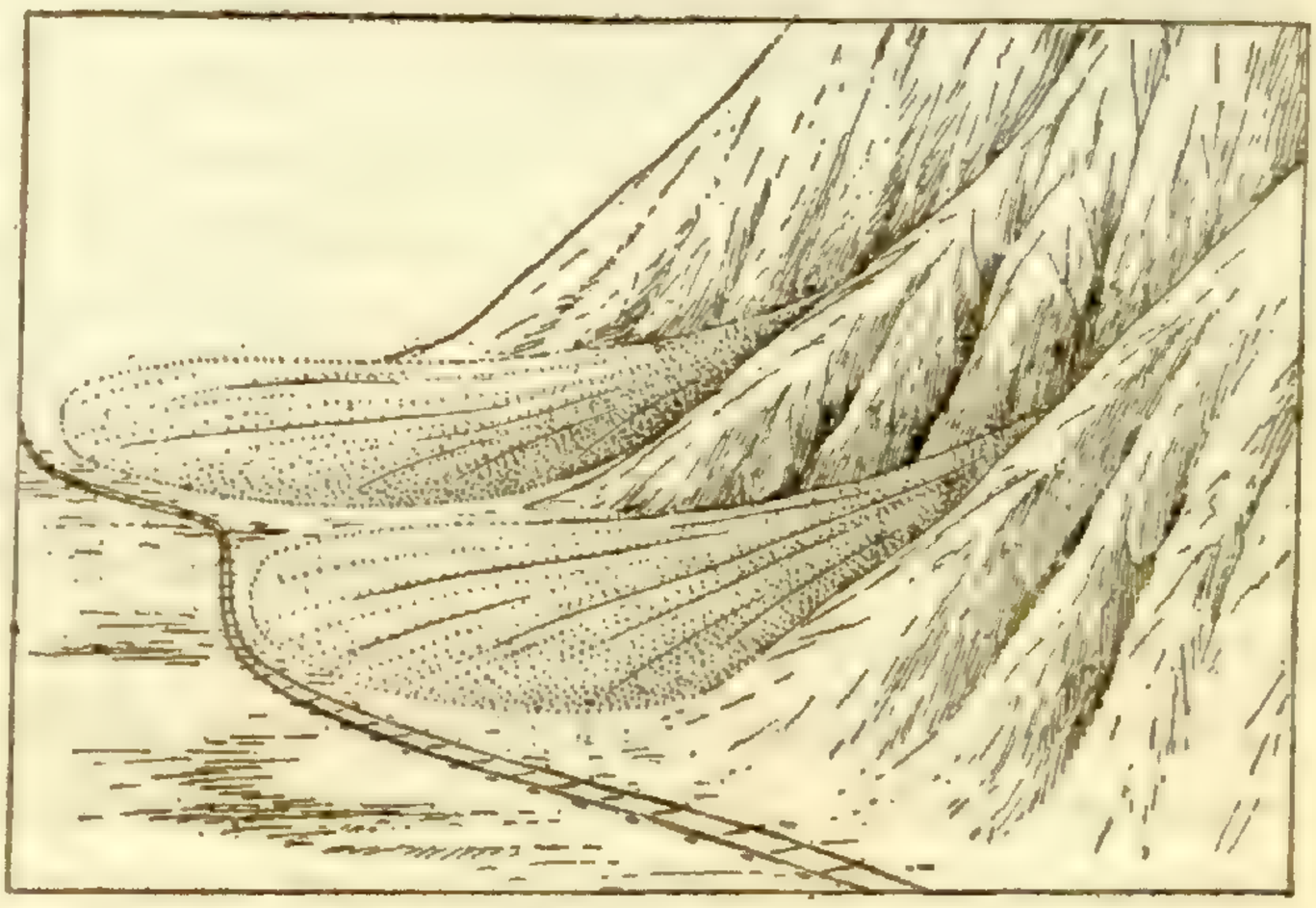

FIGURE 42.—Alluvial fans in Poncha Canyon. The material that has been swept out of two ravines in the mountains is spread out in semicircular fans, which the railroad is obliged to pass around in two sharp curves.

The canyon is narrow and V-shaped as far as Mears Junction, where it abruptly changes to a rather broad valley with a flat, swampy bottom, which bears all the marks of having been occupied by moving ice—that is, by a glacier.[49] At Mears Junction a branch railroad turns to the right and after circling about over the main line turns back on the left and climbs the mountain slope to

Mears Junction.

Elevation 8,431 feet.
Denver 226 miles.

[49] A glacier that occupies a rather broad, flat-bottomed valley almost invariably builds a ridge at its lower end, composed of fragments of rock mixed with clay that it ground away from the rocks over which it passed. All this material is carried on or in the moving mass of ice and is laid down at its extremity in a ridge that is known as a terminal moraine.

If Poncha Valley had once been occupied by ice it should contain some trace of a terminal moraine, although a moraine in a narrow valley may be more or less washed away by the stream after the ice has disappeared. A close examination of the side of the valley below Mears Junction shows such an accumulation, though it may not be noticed from the moving train. It consists of a distinct ridge of loose material which projects from the east (left) wall of the valley and causes the stream and the railroad to curve to the right in order to pass it. At the point where the railroad rounds

Poncha Pass, which stands at an altitude of 9,059 feet, and then descends into San Luis Park. Curiously enough, this branch line, in the heart of the Colorado mountains, has one of the longest stretches of straight track in this country—52 miles without a curve. Poncha Pass is much lower than Marshall Pass, and the traveler may look down into it when he is part way up the mountain.

Above Mears Junction the character of the valley is different in different parts, making the answer to the question whether it was occupied by ice somewhat doubtful.[50]

About 2 miles above Mears Junction the valley is again wide and flat-bottomed and has all the features generally attributed to occupation by ice. In this wide part of the valley the railroad crosses to the east side, where it runs for nearly a mile, and then swings across the creek and returns on the opposite slope. As the road curves across the creek the traveler may see by looking upstream that this branch of the valley is not broad or U-shaped and was therefore probably never occupied by ice. As the train climbs the west wall of the valley many interesting views of the features described above come into sight. It turns in around the head of every ravine and then out around every projecting point, as shown in Plate LXIX, *B*, until finally it comes to the top of the hills that face the valley. On one

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the outermost point of the moraine there is a sign marked "Yard limit." Here, then, is a fragment of a terminal moraine, which indicates that the valley above has been broadened and its walls steepened since it was carved by running water, so we must conclude that a great glacier long ago gathered on some of the high peaks that border the headwaters of Poncha Creek and flowed down to this point.

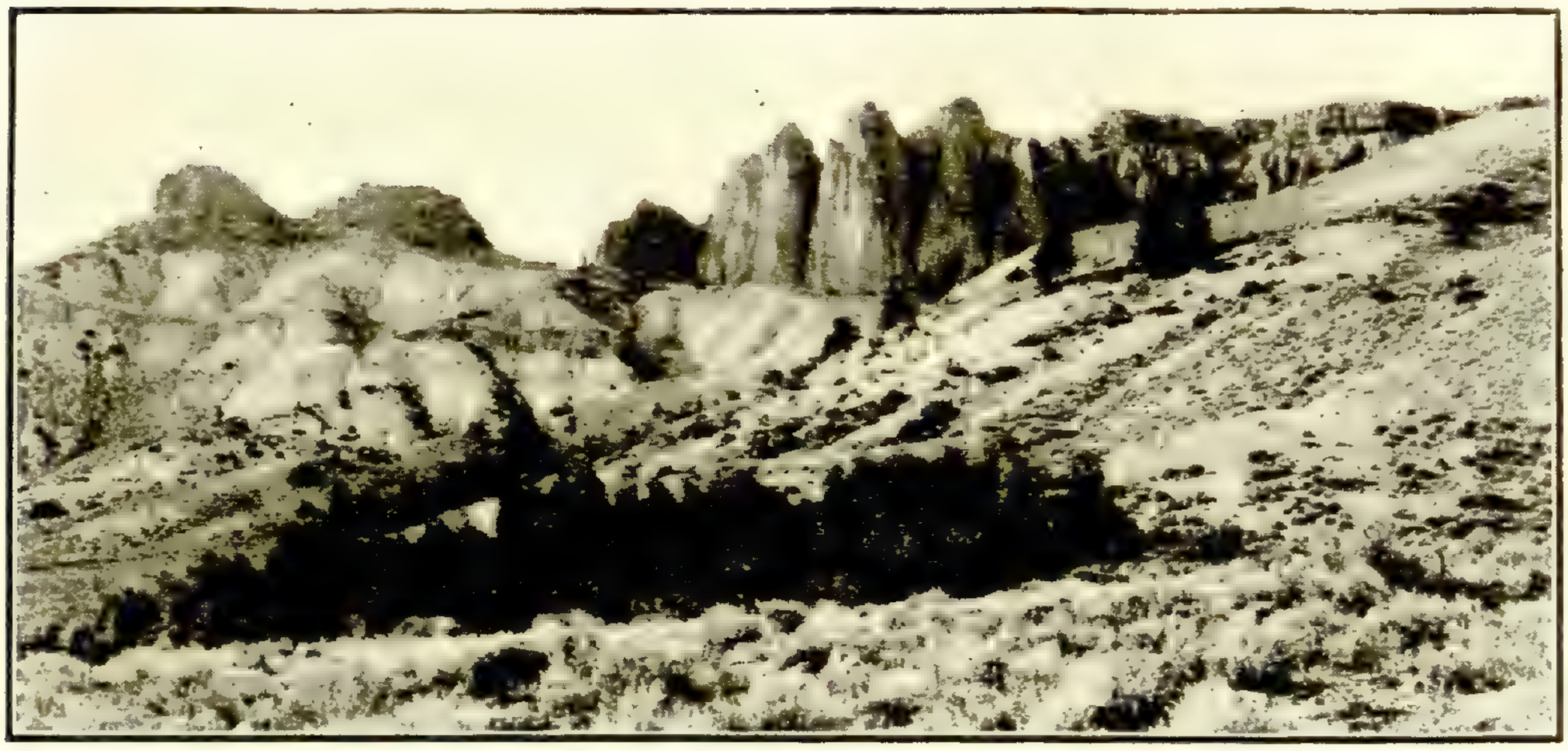
[50] About a mile above Mears Junction the valley changes from a broad, flat-bottomed swale to a narrow rocky ravine down which a glacier could probably not have moved without scouring it and changing its form. Where, then, did the glacier come from that scoured the valley at Mears Junction and built the terminal moraine a short distance below? It is not apparent from the train where this body of ice could have originated, but if the traveler could climb some of the low hills on the right he would find that they are composed of gravel and sand, and that instead of being the foothills of the mountain they are only low hills that separate Poncha Creek from the wider valley of a tributary on the west, which drains the valley between Ouray and Chipeta peaks and joins Poncha Creek through a narrow gap in the hills just above Mears Junction. It thus seems that the glacier came down this broad valley before the hills on the west side of Poncha Creek were built and that it extended down the main valley to the terminal moraine already described and then retreated. After a long interval it readvanced, though not so far as formerly, and built on the west side of Poncha Creek a terminal moraine which now could be easily mistaken for the normal walls of the valley. Another glacier must have come down Poncha Creek, for the valley broadens a short distance farther up and has all the appearance of having been occupied by ice. This glacier came down the valley of the east fork, which has been scoured out until its cross section is a symmetrical U. This glacier originated near Poncha Pass and extended only a few hundred feet into the main valley.

A. MARSHALL PASS.

View from the hills on the south. This pass was discovered in 1873 by Lieut. William L. Marshall. Its striking feature is the lack of the ruggedness that characterizes many of the other passes through the Rocky Mountains. Photograph by Whitman Cross.

B. OURAY PEAK.

This view shows the tortuous route followed by the railroad in its climb to Marshall Pass, which lies to the left, behind the shoulder of the mountain. The great glacial cirque in the northeast side of the mountain looks like a crater, and on that account the mountain has been called a volcano. Photograph by the Detroit Publishing Co.; furnished by the Denver & Rio Grande Western Railroad.



SPIRES OF VOLCANIC ROCK NEAR SAPINERO.

Much of this country was once covered with volcanic tuff consisting of fragments of lava of all sizes, which is bedded like shale or clay. It is soft and is readily cut by rain and streams into beautiful and fantastic forms. Photograph by Willis T. Lee.

B. INTRICATE EROSION OF VOLCANIC ROCK.

This mass of volcanic tuff is so dissected by rain erosion that it consists only of numberless spires and pinnacles. It makes picturesque cliffs that are hard to climb. Similar sheets of tuff cover the hills on both sides of Gunnison Valley. Photograph by Willis T. Lee.

C. SHEEP IN THE GUNNISON COUNTRY.

Many sheep are pastured in the Gunnison country. In midsummer they reach the higher slopes of the mountains, as shown in this view. Photograph by J. F. Hunter.

of the last bends the traveler may look down upon Poncha Pass, but from a distance so great that good eyesight is needed to distinguish even the telegraph poles that mark the line of the railroad. The chain of high peaks which lies behind the pass and which is known as the Sangre de Cristo Range here begins to loom up, and as the journey continues it grows steadily in apparent magnitude until it is lost to view over the summit of Marshall Pass.

As the train continues to climb upward the traveler will observe that the slopes become less and less rugged, and he soon begins to realize that the mountain masses about him, which looked so formidable when seen from below, are really only the foothills of the higher range and that many of these foothills have a nearly common height and are relatively flat topped. These flat tops stand at an altitude of 9,300 to 9,500 feet and may correspond with the rolling plain at the north foot of Pikes Peak and with the tops of the Front Range as seen from Denver. Their equivalence with those features can not be regarded as proved, but they suggest that at one time much of the mountain region of Colorado was a rolling plain above whose generally even surface only a few high knobs projected. Later this surface was upraised to its present position, and the mountains as we know them to-day were carved from the uplifted mass.

As soon as the railroad reaches the top of the hills that front the valley it changes its course to one directly toward Mount Ouray, which is the most conspicuous feature in the landscape. The road winds considerably, but from time to time the peak can be seen from either side of the train, though the best views are from the left. The peak is not symmetrical, but looks as if some giant had taken a great bite out of the side next to the traveler, as shown in Plate LXIX, *B*. And, indeed, a giant has taken a bite out of the side of the mountain, but the giant was a glacier that once lay high up on its slopes and that gradually ate out a great amphitheater or cirque, as it is called by geologists.[51] This cirque looks large even

[51] The exact method by which a glacier excavates an amphitheater or cirque is not very well understood, as all the work is done under the ice and hence can not be seen. It can be judged only by the form of the cirque after the glacier has melted away.

The term glacier means moving ice. The snow falling on a mountain side consolidates into ice under its own weight and finally becomes so heavy that it begins to move down the slope. In doing so it takes with it some of the underlying rock to which it has frozen, and this action, repeated many times, tends to produce a hole in the mountain side. As the tendency is to pluck out the rock equally in all directions from which the ice moves to the point of outlet the cirque has a semicircular shape and the plucking tends to cut back horizontally, so that the floor of the cirque is nearly level or it may be slightly deepened so as to form a rock basin. The walls of cirques in many kinds of rocks stand nearly vertical, but the walls of the cirque in Ouray Peak, which are composed of granite, take on a more gentle slope, as shown in Plate LXIX, *B*.

from the train, for it is about half a mile wide and probably 1,000 feet deep, but what must it look like when viewed from its rim!

Ouray Peak is supposed by some to be an extinct volcano, probably because of the resemblance of this cirque to the crater of a volcano. One of the best places from which to see this cirque is Grays siding, at an elevation of about 9,673 feet. Here the locomotive may take water, and the traveler may have an opportunity to step from the train and obtain a view of the mountain and the surrounding features.

A short distance above Grays siding extensive views appear on the left at many places. The chief points of interest are the peaks of the great Sangre de Cristo Range, and at their base the upper end of San Luis Park. Farther up the railroad the slopes on the left are very steep and are covered with a mantle of trees. The trees are not very large or very thick, but they conceal and soften rocky slopes that would otherwise be bare. Here the traveler may see the blue spruce for which Colorado is noted. Only the young growth has the characteristic bluish-green color, but when the cones have reached their full growth the tree is one of the most beautiful in the forest. In midsummer these slopes form a sea of green; but if the traveler should cross the pass after the middle of September he will see the aspens in a golden blaze, and even in the thick forest he may see specks of yellow as brilliant as any of the "colors" in the prospector's pan in the early days when he struck "pay dirt."

Beyond milepost 239 the railroad runs along the side of a bouldery ridge at the foot of the bare cone of Ouray Peak. The traveler is at first so far below the summit of this ridge that he probably does not realize that it is a moraine which was evidently formed by one of the last glaciers that existed on the south slope of the mountain, but when he is a little nearer the summit of the mountain he will be able to see the small cirque which this glacier excavated, though he will notice that it is not nearly so large as the cirque which he saw from Grays siding. The reasons for the difference are that the glacier which lay on the east side was in the lee of the mountain and received more snow than the other one, which was exposed to the strong west wind, and that the snow which fell upon the glacier that faced the east was not readily melted, whereas the other glacier, which faced the south, must have received the full warmth of the sun's rays. As the glacier on the east side was thus favored in the accumulation of snow and in the slight melting of the ice it grew apace, whereas the one on the south side was always small and doubtless soon dwindled away.

Beyond the moraine the railroad passes through a swampy flat, which is possibly the cirque of a much older glacier than those just described. The traveler will see on the right the station of a ranger who guards the national forest. Although his station is desolate and the passing trains are his only diversion this ranger must remain here on duty to prevent forest fires and to look after the interests of the Forest Service. At last the train stops in a small cut, and the traveler is at the summit of Marshall Pass, more than 2 miles above the level of the sea. This pass as it appears from the hills on the south is represented in Plate LXIX, *A*. The view from the summit, like that from many high mountains, is not so striking as a view from a point lower down, but it includes a vast expanse of country, especially on the west. Few real mountains can be seen in that direction, and the high land in sight consists mostly of vast plateaus which lie at different elevations. The pass was named in honor of Lieut. William L. Marshall, who was the first white man to cross it, in 1873.[51a]

Marshall Pass.

Elevation 10,856 feet.
Denver 240 miles.

[51a] Marshall Pass was discovered in 1873 by Lieut. William L. Marshall, later chief of engineers in the United States Army, not as the result of systematic exploration, but in order to find relief from toothache. The following account of the discovery is condensed from a recent article on the subject by Thomas F. Dawson in "The Trail" (Sept., 1920), the official organ of the Society of Sons of Colorado.

In 1873 Lieut. Marshall, in charge of the Colorado branch of the Wheeler Survey, had spent the summer and autumn in the San Juan region, but on the approach of winter the snow became too deep for mountain exploration and he decided to abandon work and go to Denver. It was arranged that the party should follow the regular route by way of Cochetopa Pass, but as Lieut. Marshall had a very painful toothache, he decided to strike out on some shorter route so as to reach Denver ahead of his party and to find relief from his suffering. He accordingly started with one companion, Dave Mears, on mule back and with one pack animal to find a short cut. He first tried to cross the range west of Twin Lakes but found the snow too deep; then he tried an entirely new route at the head of Gunnison River, and after a hard struggle through fallen timber and deep snow he reached the summit in a pass which he had seen from a distance but never crossed. Lieut. Marshall realized that the pass he had discovered was one over which a road or even a railroad could easily be constructed, so despite the toothache and the icy wind the party spent a day and night on the summit making observations of the temperature and barometer and preparing a profile showing the approaches on both sides.

When the observations were completed the party pushed on to Denver, where a dentist soon relieved the toothache. In a short time the news of the discovery of the pass became noised about and Lieut. Marshall was waited upon by a delegation of prominent citizens who, with true western push, organized the Marshall Pass Toll Road Co. and in a few months completed a wagon road through the pass.

What would the traveler of to-day think of making a mule-back journey of 300 miles in the snow across the mountains of Colorado to find relief

The railroad cut at the summit of the pass is in a volcanic breccia made up of bombs and other fragments thrown out by a volcano and afterward consolidated and cemented into a bed of rock. The source of this volcanic material is not known, but it probably came from the south, where the eruptions were many and violent, though they did not extend into this region. This breccia is much younger than the rocks of Ouray Peak, and it therefore does not indicate that that mountain is a volcano.

The steepest railroad grade on the east side of the summit is 4 per cent, or 211 feet to the mile, a grade that is maintained from a point not far above Mears Junction to the summit, a distance of 14 miles. The grade on the west side is the same from the summit of the pass to a point about a mile below Chester, a distance of 9 miles. As the maximum grade on the standard-gage main line is only 3 per cent, or 158 feet to the mile, a change in gage here would probably mean an entirely new location, so as to avoid the steep grades and short curves.

On emerging from the snowsheds at the summit the traveler has spread before him on the left the long slope down which the railroad winds with many loops and turns. This side of the mountain is more nearly treeless than the east side, because it is much drier, for it is swept by dry winds that have passed over the arid plateaus of southern Utah and Arizona. There are no indications that glaciers ever existed on this side, for the entire slope is exposed to view and nothing resembling a terminal moraine can be seen. This fact also is due to the strong west winds and the drier atmosphere on the west side and to the greater heat of the sun's rays, which aided the melting of the snow on the south and west sides. After the train loops back directly under the pass there is little of interest to be seen; the slopes are generally smooth, and the valley is without scenic attractions.

A short distance west of Marshall Pass the railroad goes from volcanic breccia to granite and then onto quartzite and shale similar to those seen below the Ouray or Leadville limestone in both Eagle River canyon and the canyon of Colorado River above Glenwood Springs. These rocks are not strikingly exposed and probably will be detected only by those who look specially for them.

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from a toothache! Such a trip would be bad enough to make under present conditions, but what must it have been through an unbroken wilderness and across the backbone of the continent! Truly the "winning of the West" called for courage and endurance of which the traveler of to-day, with all the comforts and even luxuries of travel, can have little comprehension.

The railroad gradually descends the slope, and at Chester it is at the level of Tomichi Creek. For some distance the valley is small and narrow, but farther on it opens, and crops of hay may be seen on the flood plain. The chief industry of the country is stock raising, for the high mountains afford excellent summer pasture and the bottoms along the creeks produce hay for the subsistence of the stock during the winter. Cattle may be seen on the range at many places, especially in midsummer, and bands of sheep find pasture at the foot of the highest mountains. (See Pl. LXX, *C*.)

Chester.

Elevation 9,412 feet.
Denver 249 miles.

Below Chester the valley expands, and at Sargent the stream, which the railroad has been following, is joined by a large branch from the north. Sargent is a busy railroad point which still bears the marks of a frontier settlement. Here "helper" engines are kept to assist the trains up the heavy grade to the summit. The rock near Sargent is mainly granite, but it is not conspicuous, for most of the slopes are smooth and round and few ledges are visible. The granite extends as far as milepost 263, where it is replaced by sandstone (Dakota), which forms a pronounced hogback on both sides of the tracks. This hogback forms one edge of a broad, flat basin of sedimentary rocks that extends practically to Gunnison. Where first seen the Dakota sandstone is overturned, as shown in figure 43, showing that the downfolding of the basin was accompanied by a strong thrust from the east.

Sargent.

Elevation 8,477 feet.
Population 288.
Denver 257 miles.

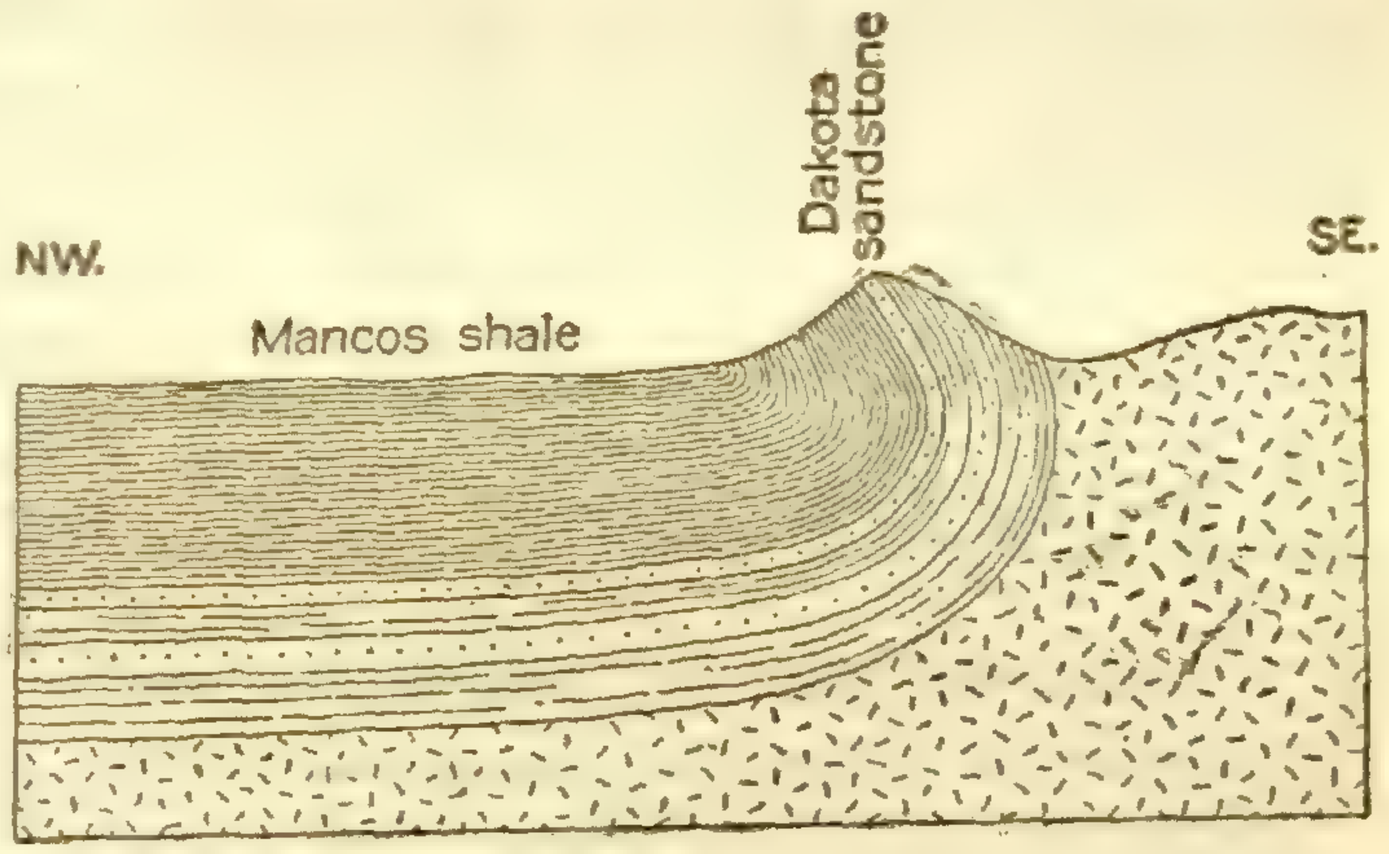

FIGURE 43.—Overturned eastern rim of the syncline at Crookton. Dakota sandstone dips steeply to the southeast.

The Mancos shale forms the surface of the inner part of this great basin for a long distance. This shale is so soft that it is seldom seen in outcrop, but it has a decided effect in subduing the features of the landscape. The valley has a width of 2 or 3 miles, the slopes bordering it are gentle, and the hills are low. In the midst of the broad valley, or rather on its north (right) border, is a prominent mountain called Tomichi Dome, which rises more than 2,000 feet

above the level of the valley. As shown in figure 44 this mountain is a great stock or mass of granite, much younger than the granite of the main mountains, that has been forced up through some crevice from below. It is much harder than the surrounding shale and hence stands up as an isolated mountain mass. The elevation of the valley here is so great that few grains will mature, but fine crops of hay are grown and the level valley floor is dotted here and there with ranches. Doyle, the center of much of this fine meadow land, is connected by stage with Waunita Hot Springs, about 8 miles to the south, which is said to be a very beautiful health and pleasure resort.

Doyle.

Elevation 8,062 feet.
Population 122.*
Denver 270 miles.

Below Doyle the valley grows narrower, and within about 3 miles from the town the Dakota sandstone rises from the floor of the valley and makes prominent ledges on either side. This sandstone is underlain by the variegated shale and sandstone of the Gunnison formation, and this in turn rests directly upon the granite, which forms the foundation of this mountain region. The Dakota sandstone rises only a few hundred feet above the level of the stream, and the underlying rocks are worn into fantastic shapes, as can be seen on the north (right) side of the valley.

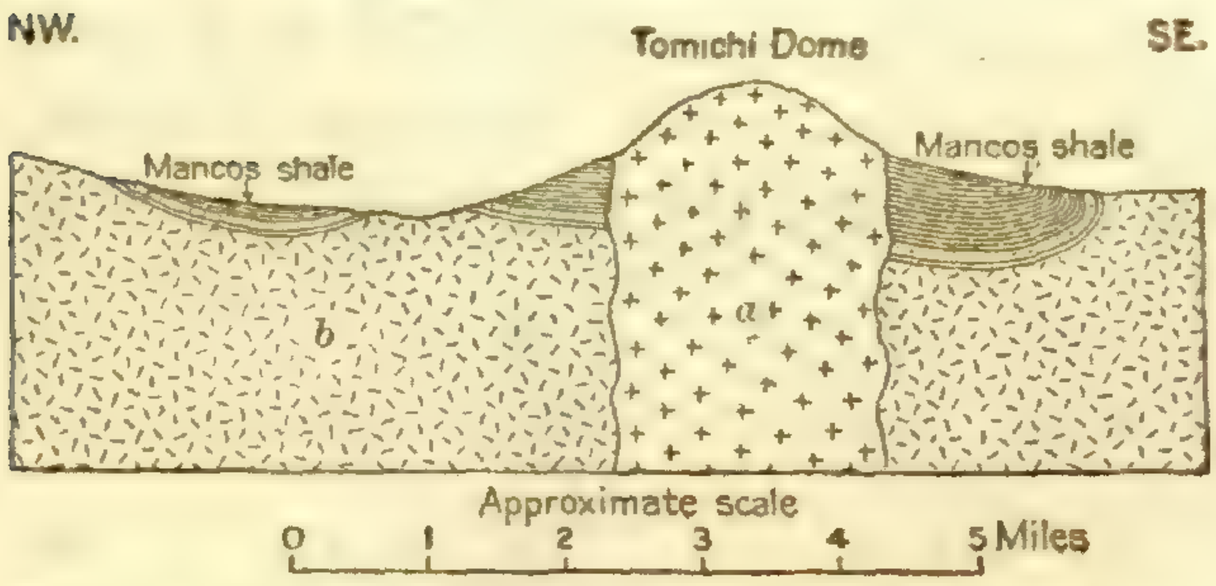

FIGURE 44.—Section through Tomichi Dome, showing the great mass of crystalline rock (*a*) that has forced its way upward, while in a molten condition, through the older granite (*b*) and sedimentary rocks.

From the point where they first appear to a point a few miles beyond the town of Gunnison the Dakota and the underlying Gunnison formation on the north side of the valley are continuously from 50 to about 300 feet above the level of the stream. In general, the valley continues wide and includes many hay fields.

Parlin.

Elevation 7,952 feet.
Population 90.*
Denver 277 miles.

Parlin, at the mouth of Quartz Creek (see sheet 6, p. 182), is the principal town in this area. It was formerly connected with Buena Vista by a narrow-gage line of the Colorado & Southern Railway, but owing to the caving of the tunnel at the summit of the range service on this line has been discontinued. This branch was originally built down the valley to Gunnison, and the old track is visible at several places on the right. On the south side of the valley the sedimentary rocks can be traced to Parlin, but below this place the granite that forms the lower slopes is overlain by a great mass of volcanic rocks. These rocks cover every high point that projects

into the valley from the south between Parlin and Gunnison. Two miles below Parlin Tomichi Creek is joined from the south (left) by Cochetopa Creek, down which in 1853 came the exploring party which gave its name to this county. This party was one of several authorized by Congress to explore for the best route for a Pacific railroad. The party, under the command of Capt. J. W. Gunnison, entered the mountains by the pass now known as La Veta Pass, through the Sangre de Cristo Range, and crossed the north end of San Luis Park, reaching the Continental Divide at Cochetopa Pass (altitude, 9,088 feet). (See sheet 3, p. 100.) They descended Cochetopa Creek to its junction with Tomichi Creek, and this stream to the Gunnison, and so continued down to Colorado River (then the Grand). The party crossed Cochetopa Pass on September 2 and reached the present site of the town of Gunnison about September 7, 1853.

The railroad follows Tomichi Creek to Gunnison, the county seat of Gunnison County, which is at the junction of Tomichi Creek and Gunnison River. The broad tract of level land on which it stands affords an almost ideal site for a town, and Gunnison, which was founded in 1874, has now succeeded in spreading itself over so large a part of this tract that it should be known as the town of "magnificent distances." It is a railroad junction point of considerable activity, for a branch line extends from it to Crested Butte and Baldwin, in the coal fields to the north.[52] Before the slump in the price of silver in 1893 there were two smelters here, and the town was a thriving supply point for a large mining district. Since then its business activities are almost entirely due to the fact that it is the division headquarters of the narrow-gage line and a railroad junction point. The town is the center of one of the best fishing regions of the State and the site of one of the State normal schools, and, according to some of its inhabitants, it has the finest climate and water in the world.

Gunnison.

Elevation 7,683 feet.
Population 1,329.
Denver 289 miles.

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[52] The coal field of Gunnison County is the southernmost part of the great synclinal basin of coal-bearing rocks which stretches from this place northward to White River and then westward nearly to the Wasatch Mountains in Utah. This basin is crossed by the main line of the Denver & Rio Grande Western Railroad between Newcastle and Palisade. The coal beds in this great structural basin are contained in the Mesaverde formation, which is a formation in the upper part of the Upper Cretaceous series. (See table on p. 11.)

The number and thickness of the coal beds differ greatly from place to place, and the coal they contain also differs in quality, ranging from subbituminous to anthracite. The coal of highest rank, including anthracite, is found in the southern point of the basin, near Crested Butte, only a few miles north of Gunnison. The coal in

As both the character of a country and its scenery depend entirely upon the kind of rocks in it and upon their relations to one another it is well, perhaps, to outline briefly the essential features of the geology of this region before attempting to describe the valley of the Gunnison. The most striking element of the scenery along both lines of the Denver & Rio Grande Western is the very old granite and gneiss that are exposed in the Royal Gorge, the Eagle River canyon, and the canyon of Colorado River, on the main line, and in the Black Canyon and adjacent parts of the Gunnison Valley. These rocks, which are without true bedding, have been crushed and folded until their structure is generally very complex. After they were crumpled they were planed down by the action of the weather and the streams until their upper surface was fairly even and probably lay near sea level. The land sank somewhat irregularly, and on the smooth slopes of the granite were laid down sand and gravel, which later became sandstone and conglomerate. Upon these rocks other sediments, which became shale and limestone, were afterward deposited. Some of these rocks are of Cambrian age (see the table, p. 11), and some are as late as Upper Cretaceous. These rocks then passed through many changes caused by uplift and erosion and probably during several epochs were planed down by the streams almost to sea level. The latest movement in the earth's crust has been one of elevation, which lifted the region to its present position, many thousands of feet above the sea, where the streams are vigorously attacking the rocks and cutting broad valleys or deep canyons, the results of their action depending on the kind of rock they encounter. A stream may at first cut down through relatively soft limestone and shale and may then encounter the massive granite, so that the top of the canyon may be broad and have gentle slopes (see fig. 45), whereas the bottom may be no wider than the stream that has cut it and may have practically vertical walls. The planing

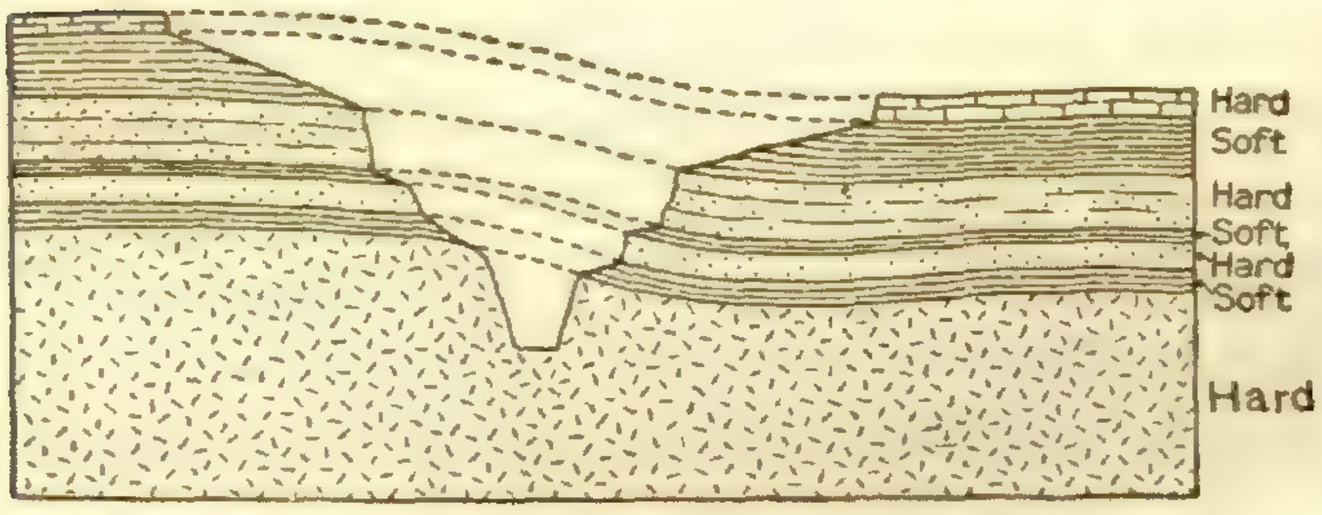

FIGURE 45.—Section showing the effect of hard and soft rocks on the form of a canyon.

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this part of the basin has been baked and converted to anthracite through the heat generated by the great intrusions as well as by the surface flows which accompanied the volcanic activities of the past. Both bituminous coal and anthracite are mined in this field and find their way to market through Gunnison. The coal output of Gunnison County rose steadily to a maximum of 640,984 tons in 1910. The output in 1918 was 582,905 tons.

down of the granite has made the surface of the land adjacent to the tops of most of the narrow canyons flat—in other words, the streams have cut trenches in mesas or plateaus.

In the Gunnison Valley another chapter has been written as an episode in the geologic history of the general region—a chapter recording events of a time, after the sedimentary rocks had been deposited, when the region was covered with lava flows or with material derived from them or from volcanic eruptions.

From the summary of the geologic history of the region just given the scenery below the town of Gunnison, even including that in the Black Canyon, may be more readily interpreted. The country for a few miles below the station at Gunnison must have been at some time long past flooded with lava. The volcanic rocks thus formed are now generally soft, but in places, as on the upland southwest of the station, they rise above the general level in great monuments or spires, making a very rough country. (See Pl. LXX, *B*.) The character of the volcanic rock—a breccia—which composes much of the surface where the slopes are smooth, may be seen in the cut at milepost 290.

Wherever the granite appears above the level of the streams they have cut into it narrow canyons, above which the slopes may be very gentle up to some horizontal bed of sandstone, which generally stands out as a mesa cap. Where the slopes are gentle and the valley is broad hay fields abound, but where the valley narrows down to a canyon the bottom can not be cultivated.

The first large canyon below Gunnison begins at a siding called Hierro (yay′rro; Denver 294.5 miles), where the top of the granite stands at track level. The top of the granite rises downstream, and within a short distance below the siding the train passes through a pretty little winding canyon, whose granite walls range in height from 100 to 150 feet. The scenery in this canyon is not grand and striking, like that in the Black Canyon, farther down, but many beautiful views may be obtained of the clear, sparkling river, the fringe of willows and cottonwoods, and the gray canyon walls. The canyon ends at Elkhorn (Denver 297 miles), a resort devoted entirely to the followers of Izaak Walton. Below this place the canyon widens out, the granite decreases in height above the stream, and the slopes above the granite include horizontal beds of sandstone, so that they are made up of a number of mesas or terraces. Hay ranches abound in the broad valley, and opposite the village of Iola even the terrace formed by the granite about 50 feet above the bottom of the valley has been irrigated and yields flourishing crops.

Iola.

Elevation 7,450 feet.
Population 111.*
Denver 299 miles.

A mile and a half below Iola another granite canyon begins, and in a short distance its walls rise to a height of about 150 feet. From

the point of greatest height the walls decrease gradually and finally disappear near the mouth of Elk Creek, a small stream that joins Gunnison River from the north. The granite, however, does not completely disappear but extends down to milepost 306, or 1 mile above Cebolla (say-bo'yah), where it passes below water level.

Cebolla.
Elevation 7,354 feet.
Denver 307 miles.

Cebolla, which is one of the most noted resorts on the river for fishermen, is in a wide part of the valley on the north side of the river, at a mesa known as Tenderfoot Hill. The top of this mesa is 1,200 feet above the track at Cebolla. The granite does not remain below river level any great distance, for within a mile of Cebolla it forms the walls of a narrow canyon, which, however, are not more than 100 feet high. The smoothness and regularity of the upper surface of the granite and the way in which it rises and falls with reference to river level make it comparatively easy for the traveler to understand how the Black Canyon has been cut. It is evident that at the time the river established its course the granite in neither of the small canyons so far described nor in Black Canyon was exposed, for the river was then flowing on the softer sedimentary rocks that overlay the granite. As the river cut deeper into its bed it uncovered the granite, but it could not shift its course and thereby avoid the hard rock, so it had to keep at work laboriously cutting its way into the granite. Although the granite canyons about Cebolla are now shallow, they will become deeper and deeper in course of time until the entire route from Gunnison to Cimarron may be one granite canyon as deep and as impressive as the "Black Canyon." It may be well to say that this great canyon will not be seen by the coming generation nor the generation after the next, nor even the one following that; but the geologist knows that unless conditions change such a canyon will be formed, although the time may be thousands or millions of years hence.

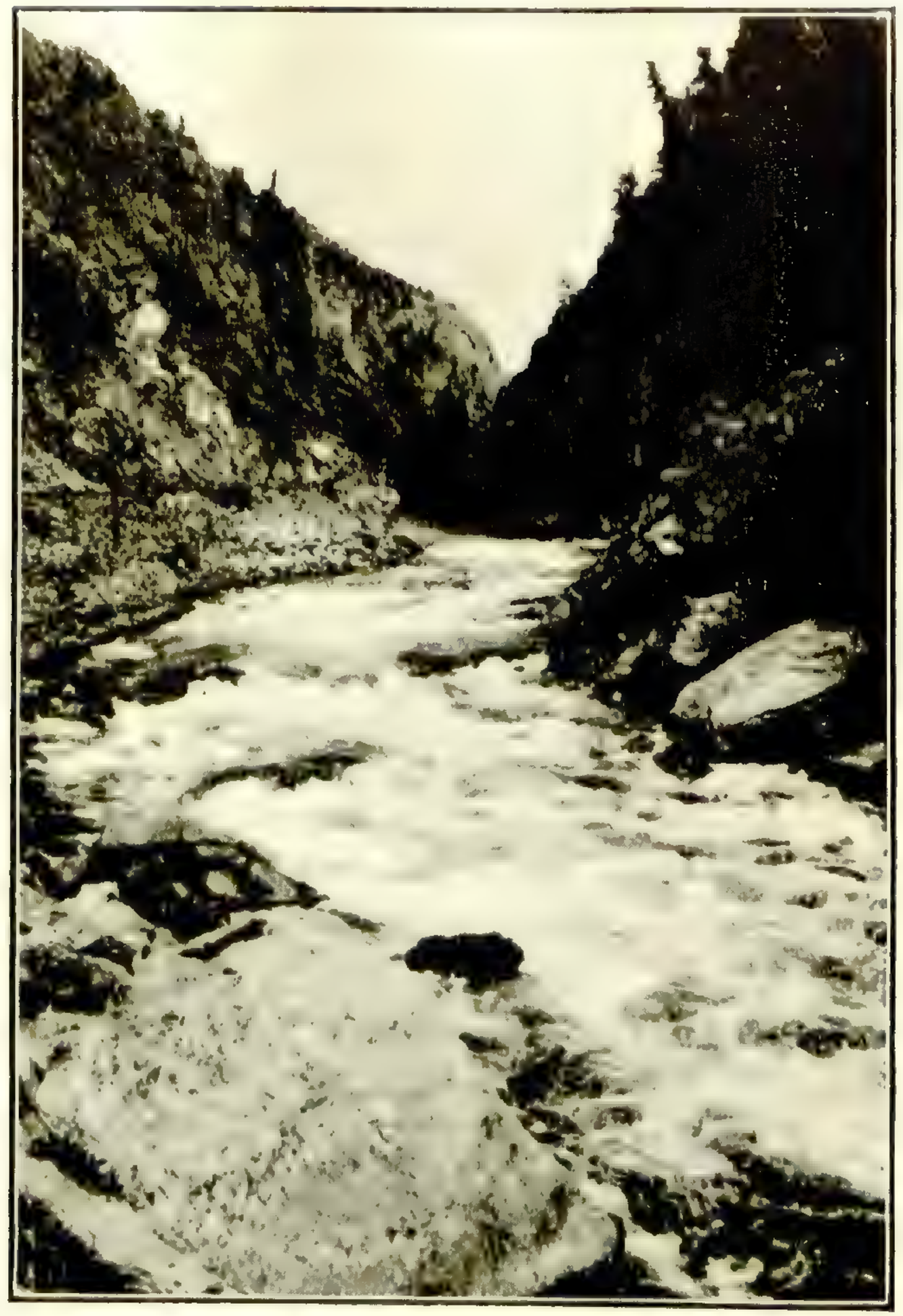
Below Cebolla the canyon is much the same as it is above that place, except that the slopes above the granite become greater and in places are composed of vast masses of volcanic breccia that weather into fantastic forms. Where the granite is above the level of the river the canyon is more or less rugged, but where it is below the surface the valley is wide and the slopes are smooth and gentle.

Sapinero.
Elevation 7,255 feet.
Population 103.*
Denver 314 miles.

Near milepost 313 the granite passes below the level of the river and remains concealed as far as the village of Sapinero (sah-pe-nay'ro), which is a noted fishing resort and the junction of the branch railroad that runs southward 36 miles to Lake City. From the station at Sapinero the traveler, by looking back, may obtain an excellent view of a great cliff of volcanic breccia (see Pl. LXX, *A*), and by looking forward he may see the granite

A, B. BLACK CANYON OF THE GUNNISON SEEN FROM ABOVE.

Views from the automobile road that follows the brink of the canyon for several miles. This canyon is a close rival of the Royal Gorge and like it may easily be seen from both the top and the bottom. These pictures show the even surface of the plateau in which the canyon is cut. Photographs by Willis T. Lee.



C. ROUGH WATER IN BLACK CANYON.

When seen from the rim of the canyon Gunnison River appears like a placid brook, but a nearer view dispels this idea. Photograph by Marius R. Campbell.

UPPER PART OF BLACK CANYON.

The rough granite walls are about a thousand feet high. The beautiful stream of clear, sparkling water tempts the traveler to stop and try his luck at casting a fly. Photograph furnished by the Denver & Rio Grande Western Railroad.

rising athwart the pathway of the stream; but even this hard rock has not proved to be an insuperable barrier to the stream, which has trenched it in Black Canyon seemingly as easily as if it had been soft shale.

The Lake City branch follows the main line for a mile and then turns to the southeast (left) up Lake Fork. It was nearly to this point that Capt. Gunnison followed the river in 1853, but finding that the canyon below was apparently impassable, he turned to the south, then struck westward across the mesas to the Uncompahgre Valley, at the site of Montrose. The automobile roads also avoid the canyon. The main road divides at Sapinero, one branch following the route of Capt. Gunnison and rejoining the railroad at Cimarron (sim-ah-rrohn′), and the other climbing west of Sapinero to a bench on the slope about 500 feet above the station and then following this bench on the brink of the canyon for an air-line distance of over 6 miles. Next it climbs to the top of the Black Mesa and avoids the lower canyon by a long detour to the north. This road affords one of the most striking and picturesque drives in the State. At the point where it leaves the canyon it is fully 1,000 feet above the roaring stream, and, as shown in Plate LXXI, *A*, *B*, the walls appear to be vertical. Gunnison River is still actively engaged in cutting its canyon deeper, as shown by the rapid current (see Pl. LXXI, *C*) and the roughness of the water as it rushes down the rocky bed.

Black Canyon is noted for its awe-inspiring beauty. Of the canyons which the traveler sees on the lines of the Denver & Rio Grande Western Railroad, the Royal Gorge easily holds first place, but the Black Canyon as a scenic feature is a close second. The form of this canyon, like that of the Royal Gorge, depends on the character of the granite or gneiss. Where the rock is massive the walls are unbroken and nearly vertical, but where the rock is banded and composed of layers of different hardness, as it is in most places, the walls may recede gradually and be very jagged and irregular. Some irregular walls are shown in Plate LXXII.

At the mouth of Lake Fork the canyon walls are about 200 feet high, but their height increases downstream, until at the siding of Curecanti they are 1,000 feet high. Every curve and angle in this distance presents a different aspect, and it is difficult to say which view is the finest. One of the most striking scenes is that of a pinnacle left standing at the mouth of Blue Creek, a small stream that joins the river from the south. This pinnacle has been named Curecanti Needle. It is nearly 1,000 feet high and is a striking object as seen from the railroad siding. (See Pl. LXXIII.)

The appearance of Black Canyon, like that of most features of the kind, depends largely upon the light and the condition of the

atmosphere. When seen in bright sunlight, as it generally is, it presents a view that is bright and lively. The rocks of the walls are full of color, and the trees and shrubs add to the beauty of the scene. But in dark and stormy weather the canyon becomes forbidding; it loses its color and becomes terrible to look upon. It is at its best in the evening, when the purple shadows that begin to play behind each projecting buttress present a strong contrast to the yellow sunlight on the westward-facing walls. Later the high points alone are bathed in yellow light, and the canyon slumbers in a mantle of blue light, steely above but denser in the seemingly unfathomable lower reaches.

Below Curecanti the canyon is even more wonderful. In general the walls are not so nearly vertical, but they increase rapidly in height until at a point 2 miles above the mouth of Cimarron Creek they are fully 2,500 feet high. The river, which is beautifully clear, becomes rougher as it descends, as shown in Plate LXXI, *C*, until it presents an almost continuous series of cascades.

A short distance above the mouth of Cimarron Creek the railroad crosses the river on a high bridge and there turns and runs up Cimarron Canyon, to the south, for this is as far as a railroad can be carried in Black Canyon without going entirely through the worst part of the canyon, and such a course would entail an expense that no ordinary railroad could meet.[53]

If the traveler were not satiated with canyons he would doubtless think that Cimarron Canyon is wonderful, but after traveling for 14 miles in the rocky depths of Black Canyon he longs for the free air and for the larger view which the hilltops alone can give, and the

[53] Although Black Canyon below the mouth of Cimarron Canyon is comparatively small, in both depth and length, it is one of the most difficult to traverse, and very few travelers have succeeded in passing through it.

The Black Canyon was first explored by a party of engineers of the Denver & Rio Grande Railroad, who in 1882–83 made an instrumental survey of the entire canyon, even passing through the more difficult portion below Cimarron. No records of this trip, so far as the writer is aware, have ever been published; all we know about it is that the members of the party suffered great hardship and peril. Since that time others have attempted to traverse the canyon below Cimarron, but most of them have suffered shipwreck and disaster.

About 1903 A. L. Fellows, an engineer of the Reclamation Service, and W. W. Terrence, of Montrose, made the attempt. They were equipped with a rubber raft, rubber bags for cameras, and two silk life lines 600 feet long. They lost their provisions but succeeded in capturing a mountain sheep, upon which they lived during the rest of their trip. It took them 10 days to traverse 30 miles of the canyon.

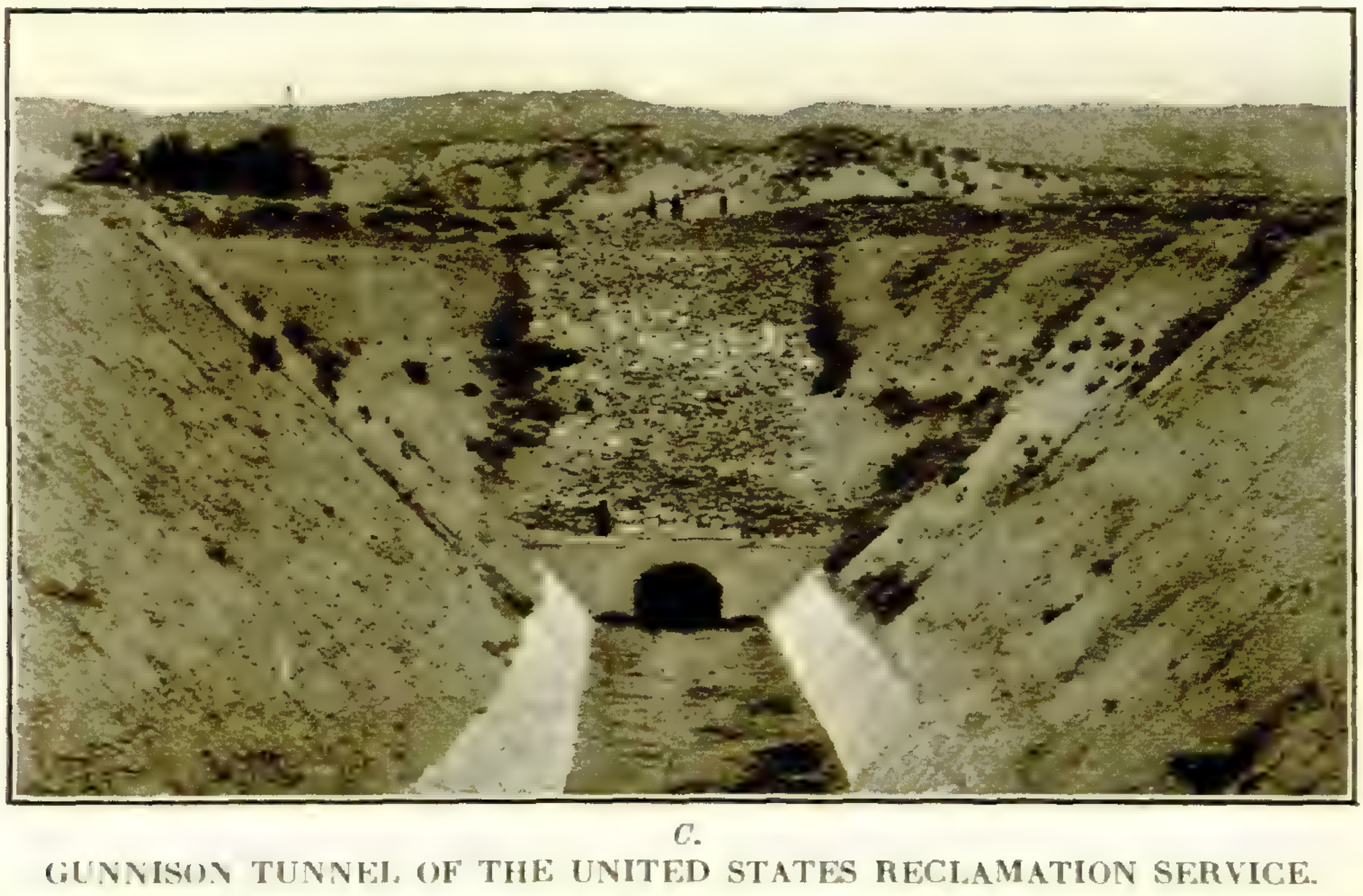
More recently Ellsworth Kolb has made a successful trip through the canyon, so that it seems probable that the Gunnison has been tamed or that man has learned how to circumvent even this raging torrent.

CURECANTI NEEDLE.

The most striking object in Black Canyon is Curecanti Needle, a pyramid of granite 800 or 900 feet high, standing at the mouth of Blue Creek. Photograph furnished by the Denver & Rio Grande Western Railroad.

A.

B.



C.

GUNNISON TUNNEL OF THE UNITED STATES RECLAMATION SERVICE.

The driving of a tunnel 6 miles through the solid rock so as to bring some of the mountain water of Gunnison River to irrigate the Uncompahgre Valley is one of the great works accomplished by the Reclamation Service. *A*, Diversion dam and intake in Black Canyon; *B*, Interior of tunnel; *C*, West portal of the tunnel. Photographs by the U. S. Reclamation Service.

sight of the station of Cimarron nestling beneath the spreading branches of giant cottonwoods is therefore most welcome. From the station it is impossible to determine why the canyon has come to an end and why one can look out through the trees into open country beyond. This change, like many others, is due to the geology, and it can be better understood by the traveler when he is at least part way up the long grade to Cerro Summit. At Cimarron the automobile road on the south side of the river joins the railroad, and together they climb to the summit on their way to Uncompahgre Valley.

Cimarron.

Elevation 6,905 feet.
Population 57.*
Denver 329 miles.

Immediately after leaving Cimarron the traveler will see that, so far as the surface features are concerned, he is in an entirely different world. He has just passed through a region of the hardest rocks, where he could see little if any soil, but here he can see no rock, at

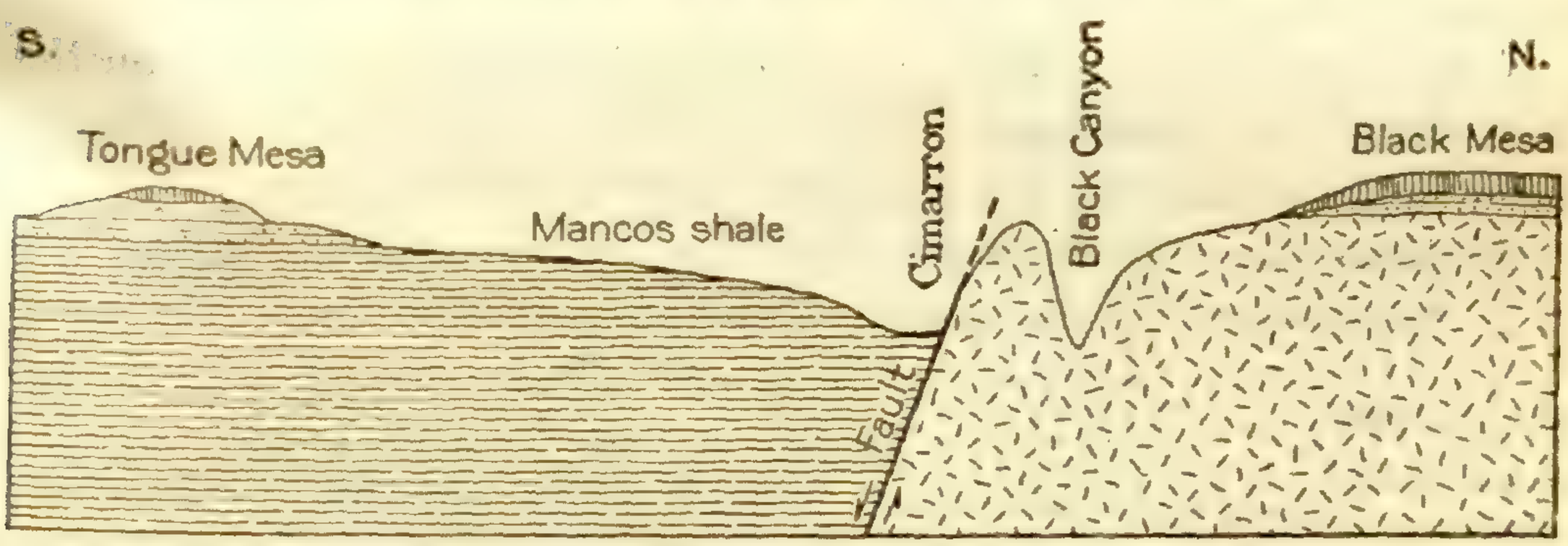


FIGURE 46.—Section across Black Canyon at Cimarron. The rocks have broken along the fault shown in the section, and the granite on the north has been forced up far above its original position.

least nothing that resembles the rocks of the canyon, though on closer examination he will see that the rock is the softest kind of shale—the Mancos shale. He may also notice that the contact between the rocks of the canyon and those of the plain is extremely abrupt, and if he could follow that contact he would find that the same beds are not in contact at all places. This variability in contact indicates that the rocks of the plain and those of the canyon are separated by a fault. In other words, the hard rocks of the canyon have been broken away from their fellows down below and lifted until they now stand actually higher than the shale, as shown in figure 46. This fault has been traced for a long distance, and in all places the edges of the sedimentary rocks are in contact with the granite. (See Pl. LXXXVII, *A*, *B*, p. 216.)

After leaving Cimarron the train begins its steep climb to the divide which separates the drainage of Cimarron Creek from that of Uncompahgre River. This grade, which is one of the steepest grades on the road, is 4 per cent, or 211 feet to the mile. In making

this climb the traveler will notice that the hard rocks through which the Gunnison has cut its canyon form a large, high mesa on the north (right), considerably higher than the summit over which the railroad passes. The shale was once probably at least as high as the granite, but it is so much softer that it has been worn away until it now lies distinctly below the hard rocks. It would thus seem that Gunnison River has gone out of its way to cut its canyon through the highest land and the hardest rocks in the region. This statement, however, represents merely the conditions as they appear to-day, but when Gunnison River first assumed this course it must have been flowing on the lowest land or it could not have remained there. At that time all this country probably stood at a much lower level and was nearly a plain, the hard rocks having been worn down as low as the soft rocks. Under such conditions the river found it as easy to flow over the granite as over the shale, and so its course was not in any sense abnormal.

In making the climb to Cerro Summit the traveler will see on the south (left) the great mass of Tongue Mesa, which owes its preservation to a protecting cap of hard rock that was originally lava which came down from some of the numerous volcanoes in the San Juan Mountains, to the south, which are visible from the open valley near Montrose. The traveler is now approaching one of the most arid parts of Colorado, where water is the most valuable natural resource. In order to irrigate a part of the great Uncompahgre Valley, which lies ahead, a long ditch has been dug to take water from far up on Cimarron Creek, carry it across Cerro Summit at a higher point than the railroad, and distribute it on the slopes to the west. Where this ditch crosses the summit it forks, and the right-hand branch, known as the Montrose and Cimarron ditch, passes under the railroad at the summit and is carried a long distance to the northwest to irrigate the broad terrace which the traveler will see later.

Cerro Summit.
Elevation 7,968 feet.
Denver 335 miles.

From Cerro Summit and the slopes beyond an extended view to the west may be obtained across the broad Uncompahgre Valley to the great Uncompahgre Plateau beyond. The ride down the slope is not particularly interesting, except as the traveler unfamiliar with the semiarid regions may see what it means to get water onto the land. The effect of irrigation is well illustrated by the verdant terrace which the traveler may see on the right at an altitude of at least 1,000 feet above the middle of the valley at Montrose. Where water is not available the surface is a desert, but where the land is supplied with all the water it needs, it will support a luxuriant vegetation.

For a long time private enterprise was engaged in irrigating small parts of the Uncompahgre Valley from such streams as Cimarron

Creek and Uncompahgre River, but these were found to be entirely inadequate for the irrigation of the entire valley. It was then decided to tunnel through Vernal Mesa (the granite mesa on the right) and bring the waters of Gunnison River to the region. The attempt was made, but funds could not be obtained to complete the project.

Cedar Creek.

Elevation 6,752 feet.
Denver 341 miles.

The Reclamation Service then took up the problem and a tunnel was started a mile below Cedar Creek and continued to the river in the almost inaccessible depths of Black Canyon, a distance of 6 miles. Work was begun in 1905, and the tunnel was formally opened by President Taft in 1909. Views of the two portals and the interior of the tunnel are shown in Plate LXXIV. By this tunnel sufficient water to irrigate 150,000 acres was obtained.[54]

From the west end of Gunnison tunnel the water is carried to Uncompahgre River by a canal 11 miles long. It is turned into the

[54] The settlement of the Uncompahgre Valley, which has had many ups and downs, began in 1882 and for a while progressed rapidly. Optimistic views on the sufficiency of the supply of water from Uncompahgre River prevailed, and by 1884 ditches for irrigating a large acreage had been projected and partly constructed. It soon proved that the water supply was inadequate, and 20,000 acres out of the 100,000 acres that had been patented passed into the hands of loan companies through foreclosure proceedings. About 30,000 acres was cultivated, but the water supply was inadequate for even this small area. In a search for an additional supply naturally Gunnison River was considered, but in order to obtain water from that river a long and expensive tunnel was necessary, yet this seemed to be the only possible chance for relief. The feasibility of the project was demonstrated in 1895 by a survey financed by local subscription. In 1901 the State appropriated $25,000 and work was begun on the great tunnel. A year later, when the appropriation had been exhausted, the State and citizens requested that the Reclamation Service complete the project. Upon examination the Reclamation Service found a better site for the tunnel, and on June 7, 1904, the Secretary of the Interior ordered the construction to begin.

The Gunnison tunnel, as finally built, is 30,645 feet long (about 5.8 miles) and has a uniform grade of 10.7 feet to the mile. The bottom is flat and is 10 feet wide, the straight sides are 10 feet high and batter outward 6 inches, and the roof is arched with a span of 11 feet and a rise of 2½ feet. The flow of water that can be delivered through the tunnel is estimated at 1,300 second-feet.

Excavation was begun on January 11, 1905, and was carried on at both ends and from a shaft 1 mile from the west portal. The tunnel complete, with concrete lining, was finished and water for irrigation was flowing through it on July 6, 1910.

It is interesting to note that this tunnel passes through the fault shown in figure 46 (p. 175), at the contact of the shale which constitutes the country rock in the western part and the granite in which the river canyon is cut. It is described in the report of the Reclamation Service as follows:

"[The tunnel was driven] 2,000 feet through a fault zone badly shattered and tilted at widely divergent angles in a very irregular manner. High temperature, hot and cold water, coal, marble, hard and soft sandstone, limestone, and carbonic-acid gas in

channel of the Uncompahgre at a point 9 miles above Montrose and is diverted lower down for projects on both the east and the west side of the valley.

At the end of 1920 water from the Gunnison tunnel was used in irrigating 65,000 acres of land which, before the completion of the tunnel, was a barren desert waste. The principal crops are alfalfa, oats, wheat, potatoes, apples, and sugar beets, listed in decreasing order of the acreage cultivated. Small fruits, onions, sugar beets, apples, garden products, and potatoes, in the order named, gave the largest returns per acre.

After passing the Gunnison tunnel, which, unfortunately, is not visible, the train descends the sloping side of the broad valley in a barren ravine, but at a siding called Fairview, half a mile beyond milepost 346, irrigated farms are spread out on both sides of the railroad. The crops that are growing here will, of course, depend upon the time of year in which the journey is made. If the traveler passes this place in midsummer he will see fine fields of oats and wheat, some corn, and plenty of potatoes, sugar beets, onions, and alfalfa. He will also see a few orchards, but this particular area is not largely devoted to fruit raising. The valley has been transformed, as shown in Plate LXXV, *A*, *B*, from a wilderness to a region of prosperous farms, and the secret of the change is only water.

In the journey down the long tangent to the middle of the valley the most striking features of the landscape are the rugged peaks of the San Juan Mountains, which are visible to the south (left). These mountains are the most rugged in the State. Most of the peaks are over 13,000 feet high, and many of them rise above 14,000 feet. The highest point in the range is Uncompahgre Peak, which has an altitude of 14,419 feet. The sawtooth top of this range is well shown in the profile visible from the train.

After passing through miles of the finest farms in the West the train reaches Ouray Junction, which is the point where this line joins the one from Ouray, Telluride, and Durango. Here the railroad turns at a right angle and proceeds a mile northward to the station in the growing young city of Montrose. This city is the distributing center and shipping point for a large district that is under high cultivation. Cereals, fruits, and vegetables, to-

Montrose.

Elevation 5,811 feet.
Population 3,581.
Denver 352 miles.

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overwhelming quantities were encountered in this section, and tunnel excavation was both difficult and dangerous."

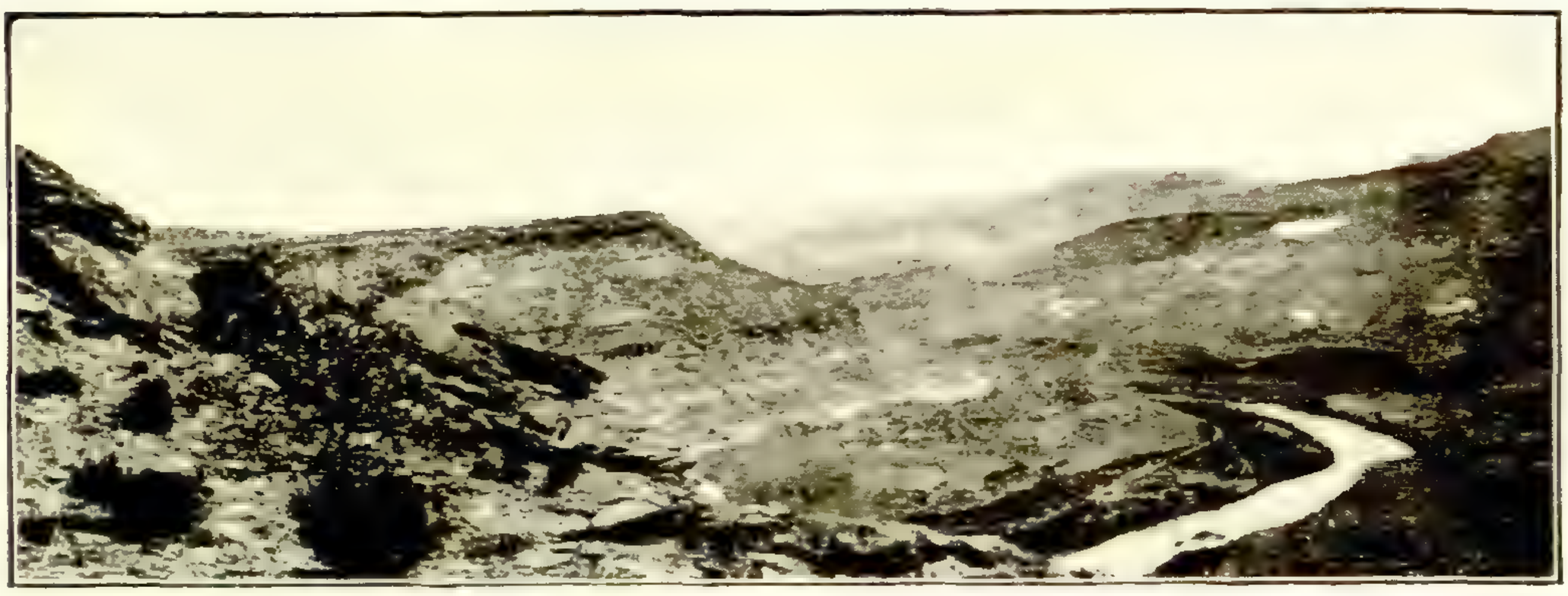
This description shows how rocks may be broken and jumbled together in a fault zone where they have moved hundreds or perhaps thousands of feet.

A. UNCOMPAHGRE VALLEY IN ITS NATURAL STATE.

The land in the Uncompahgre and Colorado River valleys before water is turned upon it is a barren expanse of adobe soil on which there is only a scanty growth of plants. It is inhabited only by jackrabbits, coyotes, and other animals having great endurance and ability to travel a long distance for water. Photograph by the U. S. Reclamation Service.

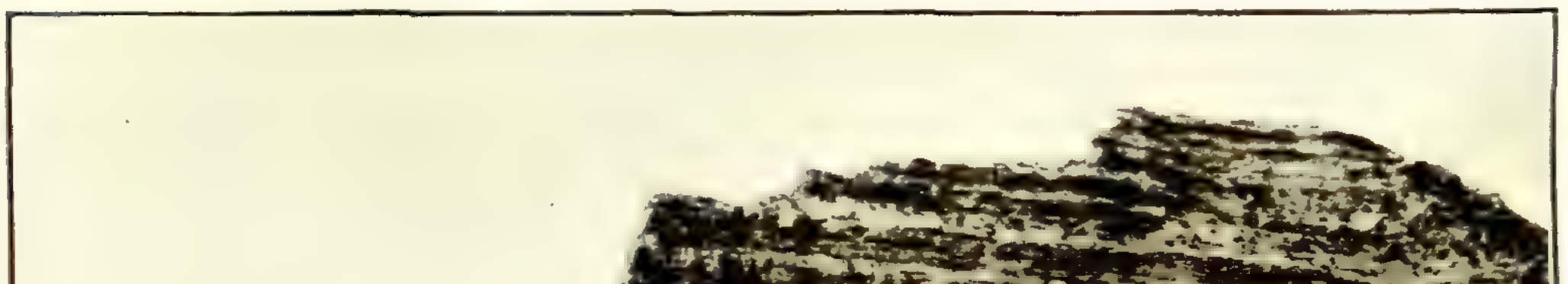
B. THE SAME VALLEY IRRIGATED.

The transforming effects of the Gunnison water are seen in the fine farms and happy homes of the Uncompahgre Valley, where once there was nothing growing but sagebrush and greasewood. Photograph by the U. S. Reclamation Service.



A. CANYON BETWEEN DELTA AND GRAND JUNCTION.

General view looking upstream. The rocks dip to the left, away from the Uncompahgre Plateau or arch. The shaly rocks in the top of the canyon walls are of maroon color, and the massive sandstone at the base is brick-red. Photograph by Willis T. Lee.



B. BRILLIANTLY COLORED SPUR OF THE CANYON WALL.

One of the projecting spurs of the canyon wall near Bridgeport consisting of alternating bands of maroon and green with here and there bands of yellow sandstone. The valley bottom supports a fairly good growth of sage but when water is put on it grows almost any kind of crop. Photograph by Willis T. Lee.

C. CROSS-BEDDED SANDSTONE.

The sandstone was once a sand bank in water; the currents coming from the right washed layer after layer of the sand over the crest of the bank and down on its sloping front, making the cross-bedded layers. Photograph by J. K. Hillers.

gether with forage plants, grow here in abundance. Two miles south of Montrose was the home of Chief Ouray, for whom the peak north of Marshall Pass and the mining town in the San Juan Mountains were named. The main line and the branches of the railroad north of Montrose were changed to standard gage in the summer of 1906.

STANDARD-GAGE LINE FROM MONTROSE TO GRAND JUNCTION.

From Montrose to Delta the railroad follows the valley of Uncompahgre River in a general course a little west of north. The country north of Montrose is more broken than that to the south, so that a general view of the valley can not be obtained from the railroad. Throughout most of the distance from Montrose to Delta the land near the river is well cultivated, but not far back from the river there is generally a line of bluffs on both sides of it, which range in height from 50 to 150 feet. These bluffs are but the fronts of extensive terraces, many of which are well cultivated, but the traveler can see only the barren shale underlying them.

For a short distance out of Montrose there is nothing to interfere with the view to the east, and the great Vernal Mesa, through which Gunnison River has cut its famous canyon, stands out in bold relief. For some distance the fault noted near Cimarron is still present, but apparently about halfway along the mesa the red sandstone beds of the Carboniferous and Triassic systems may be seen from the train as they lap onto the mesa in gentle curves. The mesa here is an arch—an anticline, as it is called by geologists—but the middle of the arch has been planed off by erosion, leaving the granite still at the surface. North of this point there is no fault on the west side of the mesa.

Along the railroad there is a high-tension electric transmission line, which brings electric power from Telluride, in the San Juan Mountains, for lighting Montrose, Delta, and other towns along the road. Olathe (o-lay'the), a place of recent growth, by utilizing the water supplied by the Gunnison tunnel is becoming a horticultural center. In passing along the railroad the traveler will note that the farmers of the valley are troubled in places with strong alkali, which makes the surface as white as if it had been covered by snow. This alkali, which is brought to the surface by flooding, due to overirrigation, makes farming difficult, but it can largely be removed by subsurface drainage.

Olathe.

Elevation 5,365 feet.
Population 491.
Denver 362 miles.

One of the most promising parts of the valley for agriculture is the terrace called California Mesa, which the traveler may see on the west

(left) as he approaches Delta. This mesa is served with water by canals which divert it from Uncompahgre River at a place far up the valley. Delta is the county seat of Delta County and was so named because it stands on the delta formed where Uncompahgre River enters Gunnison River. The south slope of Grand Mesa, the table-land to the north, is one of the most noted fruit-growing regions of western Colorado. The orchards on this southward-facing slope are protected from frost in much the same manner as those at Palisade, so that fine crops of apples, peaches, and other fruit are produced here almost every year. The towns of Hotchkiss, Paonia, Cedaredge, and Austin are particularly noted for their excellent fruit, which is carried to Delta on a standard-gage branch road and thence shipped to other markets. Considerable coal is mined at Somerset, the terminus of this branch, and finds a ready market in the Uncompahgre Valley.

Delta.

Elevation 4,980 feet.
Population 2,623.
Denver 373 miles.

From Cimarron to Delta the railroad runs entirely on the Mancos shale, to which are due the breadth of the valley and the smoothness of its sides. At Delta the shale lies in a great structural trough—a syncline, as it is called by geologists—whose eastern edge rests on the flank of Vernal Mesa and whose western edge rests on the Uncompahgre Plateau. Below Delta the railroad changes its course from west of north to almost due west, and it therefore soon reaches the edge of this shale valley and enters a canyon cut in the underlying sandstone.

A short distance from the station at Delta the railroad crosses Uncompahgre River and then runs along the bank of Gunnison River, which the traveler has not seen since he left Black Canyon. Here the Grand Mesa is in full view to the north (right). All the lower slopes of this mesa are composed of the Mancos shale, which is so soft that it generally forms valleys wherever it is exposed, but the shale in the mesa is protected by overlying sandstone that is capped by a thick sheet of solidified lava (basalt). When this lava was poured out the present lowlands had not been cut, and the whole surface stood at the same level as that of the top of Grand Mesa. The volcano or volcanic vent from which this great flow was ejected has not been definitely located, but it may have been at a considerable distance, for this sheet is probably a part of the great lava flow that covered much of this general region, a flow whose remnants can still be seen on Grand Mesa and Battlement Mesa, to the north, on the Flattops, north of Glenwood Springs, and on other high mesas. If these remnants are not a part of a single flow they are probably parts of independent flows that occurred at about the same time. As the West Elk Mountains, east of Somerset, were a center of great volcanic

activity at about this time the lava may have originated there. The striking thing about these lava flows is the enormous amount of erosion that has taken place since they occurred. The date of the flow can be fixed only as some time in the Tertiary period, but it was long enough ago to permit the removal from the valleys of rocks at least a mile in thickness.

The sandstone and interbedded shale immediately below the lava cap in Grand Mesa contain beds of coal and were formerly called the Laramie formation, which belongs at the top of the Upper Cretaceous series (see table, p. 11), but now they are known to be older and to correspond with the heavy sandstones that form the Mesa Verde, in the southwestern part of the State, and hence they are called the Mesaverde formation. The same formation carries the coal at Anthracite and Crested Butte, northwest of Gunnison. At that place the coal beds contain coal of high rank, but in the Grand Mesa, which is farther from volcanic disturbances, the coal is of much lower rank, most of it being subbituminous, or what was formerly called "black lignite." A large mine is operated at Somerset, but in that part of the mesa which is visible from the river bank west of Delta coal is mined only for local use.

On the left, but not visible in many places, is the broad upward swell (anticline) known as the Uncompahgre Plateau, which is composed of sandstones that underlie the shale seen about Montrose and Delta. These sandstones will be seen in the canyon between Delta and Grand Junction. Around the margin of the plateau the massive red sandstones are deeply cut by the streams which flow from this upland in rugged canyons that have nearly vertical walls. These canyons are visible from the trains of the Denver & Rio Grande Western Railroad from Delta to the Utah State line. The interior of the plateau is unbroken and consists of a gently undulating upland without marked surface features.

Just after passing Roubideau siding, near milepost 378, the sandstone that underlies the shale makes its appearance. This sandstone, which contains thin beds of coal, has been called the Dakota sandstone, but the best authorities now place it in the bottom of the Mancos shale, and hence the Dakota may not be present. The rocks rise rather steeply in the direction in which the train is moving, and soon variegated shale and maroon sandstone may be seen. These rocks are in part the same as those which the traveler may have seen at many places along the Front Range and which contain the huge dinosaurs described on page 70. A skeleton of one of these dinosaurs was once found across the river from Grand Junction in rocks of the same kind.

At milepost 379 the railroad crosses the river, and from this place to Grand Junction the best views of the canyon may be obtained on the left. In the upper end of the canyon the walls are composed of variegated shale and sandstone of the Gunnison formation,[55] as shown in Plate LXXVI, *B*.

At first the only part of the Gunnison formation that is seen is the upper shale, which gives to the canyon walls bands of rather strong color, but after watching these colors for several miles one would welcome any change from the ever-present maroon and green. Although the canyon is fairly narrow and there is not much land in it that can be irrigated, several attempts at irrigation on a small scale have been made. The method used employs no dams or ditches but only a current wheel, which is placed in the stream in such a position that the current turns it, and as it is provided with buckets, a small quantity of water is at each revolution lifted from the river to the top of the wheel, where it is automatically dumped into a trough that carries it to the land to be irrigated. Although this is a primitive arrangement it is excellently adapted to the irrigation of small tracts of land. A number of these wheels may be seen in the canyon.

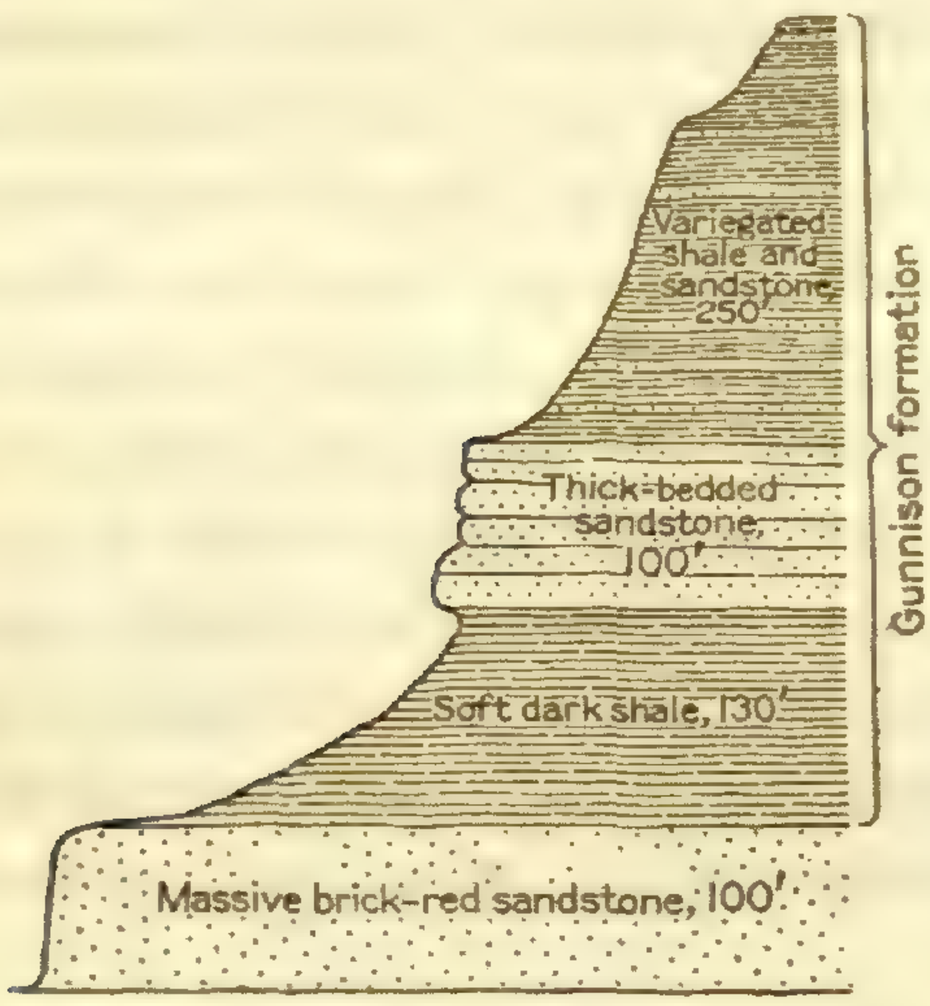


FIGURE 47.—Rocks forming the canyon wall near Bridgeport.

In general the canyon grows deeper downstream, and at Escalante siding, milepost 385 (see sheet 7, p. 198), the second member of the Gunnison formation—a hard sandstone—appears near the railroad

[55] The Gunnison formation here is composed of three parts, as shown in figure 47. The upper part, which probably corresponds to the Morrison formation of the east side of the range, is visible where the walls are low. It is about 250 feet thick and is made up of variegated shale and soft sandstone. The colors are mostly maroon and green, and in many places the bands of color are very distinct. This part is comparatively soft and consequently forms slopes that lead down from the more resistant sandstone cliffs above. The middle part of the formation is about 100 feet thick and is composed largely of sandstone that is resistant to erosion and therefore stands out as buttresses on the canyon wall with steep or precipitous faces. Although not brightly colored, it has many of the same tints as the overlying shale. The lowest part of the formation is about 130 feet thick and is made up almost entirely of shale, which in the upper part is of a dull slate color but near the bottom has many bands of strong maroon. It is generally soft and forms slopes, but the slopes are steeper than those formed on the uppermost part of the formation.

GEOLOGIC AND TOPOGRAPHIC MAP
OF THE
RIO GRANDE ROUTE
From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

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A. C. ROBERTS, Topographer

1922

EXPLANATION

		Age	Thickness in feet
B	Gravel in river bottoms and terraces	Quaternary	
F	Red shale and sandstone (Wasatch formation)	Tertiary (*Eocene*)	3,400
H	Sandstone, shale, and coal beds (Mesaverde formation)	Upper Cretaceous	2,825
J	Dark marine shale (Mancos shale)		4,000
M	Brown sandstone (Dakota sandstone)		50
N	Variegated shale and sandstone (Gunnison formation)	Cretaceous? and Jurassic	480
P	Brick-red massive sandstone	Triassic	300±
X	Granite	Pre-Cambrian	
Y	Lava flows (basalt, andesite, latite, rhyolite, and tuff-breccia)	Tertiary	

Fault

grade. Within a short distance it rises above the grade, and below it may be seen a dark shale. This shale also rises downstream, and at milepost 388 the top of a brick-red massive sandstone (Triassic) appears beneath it on the opposite side of the valley. Wherever it is exposed this sandstone, on account of its deep and uniform color and its massiveness, is the dominating feature of the canyon. As the rocks dip toward the northeast (see Pl. LXXVI, *A*) and as the general course of the stream and of the railroad is toward the northwest, the rocks exposed on the two sides of the canyon are not necessarily the same. Even if the stream followed a straight course the beds at the same level on its opposite sides in the same stretch would be different, but the difference is greatly exaggerated because the stream swings from side to side in great meanders. At many places a point on the outermost part of a bend to the left is more than a mile from the outermost part of the next bend to the right. The farther the stream swings to the left the lower or older are the rocks in the canyon walls, and the farther it swings in the opposite direction the higher or younger are the rocks in the walls.

Wherever the brick-red sandstone rises 100 feet or more above the water there is an inner box canyon with vertical walls, but where this sandstone is below the water the canyon walls recede by slopes and terraces. This compound character of the canyon is shown in Plate LXXVI, *A*. At milepost 400, 2 miles beyond Bridgeport siding, the railroad enters a tunnel that is excavated entirely in the massive brick-red sandstone, which is ideal material in which to drive a tunnel, for the roof needs no timber to support it, and the portals are equally durable. This tunnel is 2,256 feet long—nearly half a mile.

In places the walls of the canyon are about 500 feet high, but they lack both the ruggedness and the regularity that characterize the other great canyons on this route. Finally they begin to decrease in height, until, half a mile beyond milepost 410, the traveler begins to see open country, and soon he finds himself back in the same shale valley that he left a few miles below Delta. A mile farther along the train reaches the station in the small village of Whitewater. Here Grand Mesa looms up on the right as the most conspicuous feature in the landscape. On leaving Whitewater the railroad again enters the canyon, which, however, is nowhere so deep nor so interesting as it is farther up. Its walls are composed entirely of rocks of the Gunnison formation, or of rocks lying above it, and at no place does the brick-red sandstone again make its appearance. The river meanders broadly, swinging first to one side and then to the other in sharp curves which make the

Whitewater.
Elevation 4,665 feet.
Population 272.*
Denver 412 miles.

mileage of the railroad much more than it would be if the course were fairly straight.

As meanders like those in which the Gunnison flows in this canyon could not have been begun while the river was cutting the canyon they must have been there before the canyon was cut, and as geologists are agreed that such meanders can be formed only by a sluggish stream, the Gunnison of the time when these meanders were young was not so rapid as it is to-day; it was a lazy river that flowed slowly and wound about in the broad valley in which it was flowing. The meanders were therefore formed when this part of the country was essentially a shale plain, above which only here and there mountains lifted their heads. As already stated, such a plain is supposed to have been in existence when the lava that now caps Grand Mesa was poured out, so that the meanders which the traveler sees to-day in the river were probably formed when it was flowing at a level a mile higher than it is now, before any of the sandstones that now form the walls of its canyons were exposed. According to this interpretation the meanders are very old and are simply inherited from the former channel of the river.

Near milepost 420 the Gunnison formation disappears below the river, and from this point down to the junction of Gunnison River with Colorado River it appears only in places, and the canyon is cut mainly in the sandstone, shale, and coal beds of the lower Mancos. The height of the walls also declines, and finally, after skirting the bluff on the right for a considerable distance, the train passes through a small cut and crosses the bridge spanning Colorado River and is soon at the station in Grand Junction.

Grand Junction.

Elevation 4,583 feet.
Population 8,665.
Denver 424 miles (via Marshall Pass).

Grand Junction is one of the largest towns of western Colorado. It stands at the junction of the main line of the Denver & Rio Grande Western Railroad and the line over Marshall Pass, on the flat plain at the junction of Gunnison and Colorado rivers, and is therefore on the natural route of railroad travel. Colorado River especially carries a large volume of water, and as its fall above Grand Junction is considerable it affords an excellent supply of water for irrigation. Water has been taken from the river for this purpose by many private companies, but generally it has been taken out only a short distance above the land to be irrigated, and consequently it has neither sufficient head nor volume to irrigate all the land adjacent to the town. Recently the United States Reclamation Service has dammed Colorado River 20 miles above Grand Junction and is carrying the water in the High Line canal (see p. 152) to the terrace or bench land back from the river and near the foot of the Book Cliffs.

Grand Junction is the center of a great fruit-growing country that extends up Colorado River nearly to De Beque, up the Gunnison a short distance, and down Colorado River to Fruita and Loma. Apples, pears, and peaches are the principal fruits raised. Views of the orchards and the method of irrigating them are shown in Plate LXXVII, *A*, *B*. Besides fruits the valley produces vegetables, principally sugar beets and potatoes. Sugar beets find a ready market at the sugar factory at this place, and many beets are shipped here from other parts of the two valleys.

The town has broad, well-paved streets, good business houses, and a very attractive residence section, whose streets are well shaded by trees that afford relief from the rays of the sun. These trees, together with the orchards, make this part of the valley look like an oasis in a desert. A description of the scenery along the main line east of this place ends on page 158.

MAIN LINE OF RAILROAD FROM GRAND JUNCTION TO SALT LAKE CITY.

A short distance west of the station at Grand Junction the traveler's view of the valley is fairly unobstructed, and he obtains

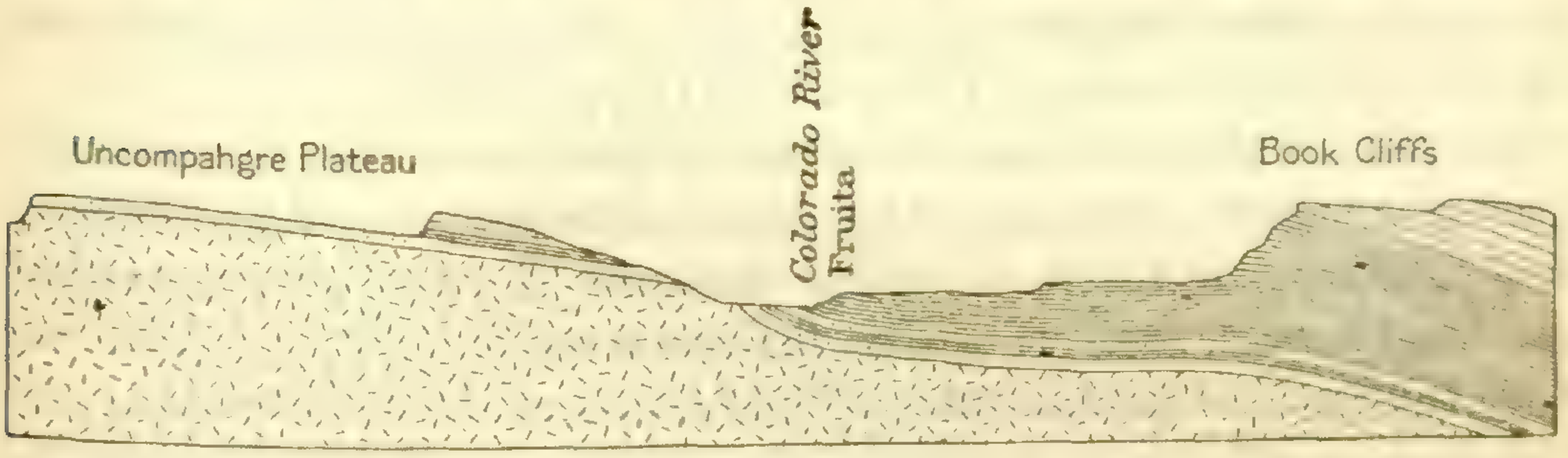

FIGURE 48.—Sketch section across the valley at Fruita, Colo.

an attractive setting for the picture of the town. The existence of this valley is due to geologic causes which can be easily understood by a traveler who desires to know something of the character of the rocks and of their attitude, or, as the geologist would say, the geologic structure. The lowest and therefore the oldest rocks lie in the great Uncompahgre Plateau or arch, which lies south of Grand Junction; the youngest rocks lie in the basin to the north and are generally known as the Green River formation. The dip of the rocks as they would appear in the sides of a great ditch, if one were cut from the top of the Uncompahgre Plateau to the middle of the Uinta Basin to the north, is shown in figures 37 (p. 148) and 48.

The Mancos shale is much softer than the rocks either above it (to the north) or below it (to the south), and it therefore tends to weather away much faster and form a valley. As the formation

dips only slightly toward the north, and as it has a thickness of about 3,000 feet, the valley which it occupies and which has been formed by its erosion is of considerable width. To the north the rocks above the Mancos shale cap the Book Cliffs, which were so named because the beds of rock when seen from a distance suggest the edge of a book lying on its side. To the south the underlying variegated sandstone of the Gunnison formation makes the slope that leads up to the great red cliffs on the Uncompahgre Plateau. The traveler may see these rocks, as already stated, soon after leaving the station at Grand Junction, and they are generally in sight on both sides of the road as far as Mack.

The peculiar shape and structure of the Book Cliffs (see Pl. LXVIII, p. 157) gives them a striking resemblance to architectural features. In their lower part they are composed of shale, which is capped by heavy beds of sandstone that lie almost flat. Nearly 1,000 feet of shale is exposed, and where it is not protected by blocks of sandstone that have fallen from the ledges above it has been cut by the rain into innumerable branching ravines separated by low ridges. Viewed from a distance when the sun is low enough to cast a shadow on one side of these dividing ridges the sculpture is marvelously accurate and sharply defined, resembling the venation of a leaf. The slope is steep, nearly 45°, and the profile of the slope and the cliff above is well shown in Plate LXVIII (p. 157).

The cliffs on the south are composed of great beds of red sandstone or white sandstone stained red by the overlying shale. At first sight these beds appear to lie so nearly flat that if they were extended they would reach entirely across the river valley and would lie far above the head of the traveler. When they are studied closely, however, they may be seen to bend down sharply as they approach the river, and in reality they pass under the stream instead of far above it. The bend in the rocks may be seen by looking back after the train has gone a mile or so beyond the station.

In this valley, as in most other irrigated parts of the West, the railroad does not traverse the area that is most highly cultivated, and the traveler may think that a large part of the valley below Grand Junction consists of land so highly impregnated with alkali as to be unfit for farming, but here and there he may catch a glimpse of the terrace or bench lands, which support the finest ranches in the valley. Along the railroad he may see some good ranches and orchards, and in striking contrast to them he may see in many places remnants of the original growth of sagebrush which covered the whole valley before it was irrigated and cultivated. This valley is the most arid part of Colorado, for, according to the records of the Weather Bureau, its annual rainfall is only 7.7 inches. The

wizard that has transformed the scene here is water. This water may first fall in the form of snow on the high peaks of the Rocky Mountains, but early in June the warm rays of the sun reach the snowbanks and convert the snow into water, a part of which plunges roaring down the steep sides of the mountain to swell the torrents in the streams below, and another part finds lodgment in the crevices and open pores of the rocks and is kept stored there until the surface water has almost disappeared. Then the rocks gradually give up their stores, and this midsummer supply appears just when it is most urgently needed by the growing crops. But how can this water be gathered and spread out on the thirsty land; and if so spread out, will it be sufficient, or if sufficient in midsummer, will it be sufficient in September, when the driest part of the season is reached? In the semiarid regions of the West these questions are of the utmost importance, and several bureaus of the Government have been for years making exhaustive studies of all the streams to determine how much water they carry and in constructing engineering works by which the water in them may be distributed over the land. The work of measuring the quantity of water in the streams has been taken up by the United States Geological Survey, because water may truly be considered a mineral, and it is the duty of the Geological Survey to take account of all the mineral resources of the country. Most people of the West are familiar with this work, but those who come from the East are perhaps unaware that reports concerning the water supply of many regions or streams may be obtained free on application to the Director of the United States Geological Survey, Washington, D. C. The method by which the quantity of water flowing in a stream is determined is described below by Robert Follansbee.[56]

As the traveler goes westward he sees that the Book Cliffs recede farther and farther from the river, and about 10 miles west of Grand

[56] Without a thorough knowledge of the available water supply irrigation enterprises are not likely to be successful. The work of the United States Geological Survey in measuring the flow of the larger streams is especially needed to insure the prosperity of the West and has been developed to meet the need. It was begun in 1888, when a camp of instruction was established on the Rio Grande in charge of F. H. Newell, who later became the Director of the United States Reclamation Service. Here were developed the methods which laid the foundation for the present work of recording the flow of streams. From this small beginning the work was expanded until now there are in the United States more than 1,500 gaging stations at which the flow of streams is measured.

Records of stream flow are not only necessary in planning successful irrigation and water-power projects but are being used by the Reclamation Service in determining the inflow of the big reservoirs it is building, by the Weather Bureau in predicting flood flow in the lower Colorado River at Yuma, by the Forest Service in determining the available horsepower at undeveloped power sites in the national

Junction they begin to lose some of their picturesqueness on account of their distance from the observer. The red cliffs on the south become more prominent and are much more dissected into fantastic forms than they are south of Grand Junction. About 11 miles west of Grand Junction the pillars, towers, buttresses, columns, and domes become so striking that an area including them, opposite Fruita, has been set aside by the Federal Government as the Colorado National Monument. By this means they will be preserved and made accessible to the general public. One of these picturesque forms is shown in Plate LXXVIII. Fruita, as its name implies, is the center of an extensive fruit-raising district, but the best part of this district is on the terrace north of the town. Much of this land is devoted entirely to the raising of fruit; but, as shown in Plate LXXVII, *A*, other crops are raised between the trees while the orchard is maturing.

Fruita.

Elevation 4,510 feet.
Population 1,193.
Denver 461 miles.

Just west of Fruita the railroad crosses Little Salt Wash and Salt Wash, two streams that head at the base of the Book Cliffs, about

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forests, and by irrigation and power companies at critical periods, especially during low water.

In determining the flow of a river the height of the water is first measured on a fixed scale called a gage. A local observer reads the gage height morning and evening and records the reading. If the record at the station is likely to be of great value, or if the station is in a remote place, it is desirable to use an automatic gage, which draws a curve on a chart showing continuously the height of the water, including every fluctuation. In May and June the warm days and cold nights cause alternate melting and freezing at the headwaters of streams that head in high mountains, so that they rise and fall regularly during a 24-hour day. The extreme daily variation may amount to 1 or 2 feet. On a gage that is placed near the head of the stream the highest stage will be reached during the day and the lowest during the night, but on one that is placed some distance downstream the highest stage may be reached during the night and the lowest during the day.

From the gage height and the contour or cross section of the stream bed at the gage, as determined by soundings made at several points in a line across the stream, the area of the cross section at the point of measurement is computed. The velocity of flow is measured with a current meter, and from the velocity and the area of cross section the quantity of water flowing past the gaging station can be determined. As the current strikes against the cups of the meter it causes them to revolve, and the revolutions in a given time are counted by means of an electrical make-and-break contact to determine the velocity of the current in feet per second.

In low water the meter is held on a rod and the engineer makes his measurements by wading. He first stretches a line across the stream to determine its width and then sounds every few feet across to determine its depth. Lastly he measures with the meter the velocity of the water at each point of sounding. Then, as he knows the width and depth of the stream, he can easily calculate the number of cubic feet of water passing this station each second (usually abbreviated to "second-feet") when

A. TWO CROPS ON IRRIGATED GROUND.

In the irrigated districts land and water are made to do double duty by providing a crop of small fruit or vegetables between the rows of fruit trees. Photograph furnished by the Denver & Rio Grande Western Railroad.

B. METHOD OF IRRIGATING ORCHARDS.

Great care and judgment are required in properly irrigating growing fruit trees. This view shows how the water is conducted to all parts of the orchard and controlled in its flow so as to get the best results. Photograph furnished by the Denver & Rio Grande Western Railroad.

A COLUMN OF SANDSTONE IN THE COLORADO NATIONAL MONUMENT.

This national monument has been set aside because of the wealth of detail in the carving and the richness of the coloring of the erosion columns of deep-red sandstone which have become separated from the parent cliff by weathering. Photograph furnished by the Denver & Rio Grande Western Railroad.

20 miles to the north. The term "wash" is applied in the West to a stream or to the bed of a stream that is generally intermittent and that carries so much material that it clogs its own channel and is thus compelled to wander over a wide area. In some places where these streams are crossed by the railroad they have cut deep channels that have nearly vertical sides. Ordinarily very little water

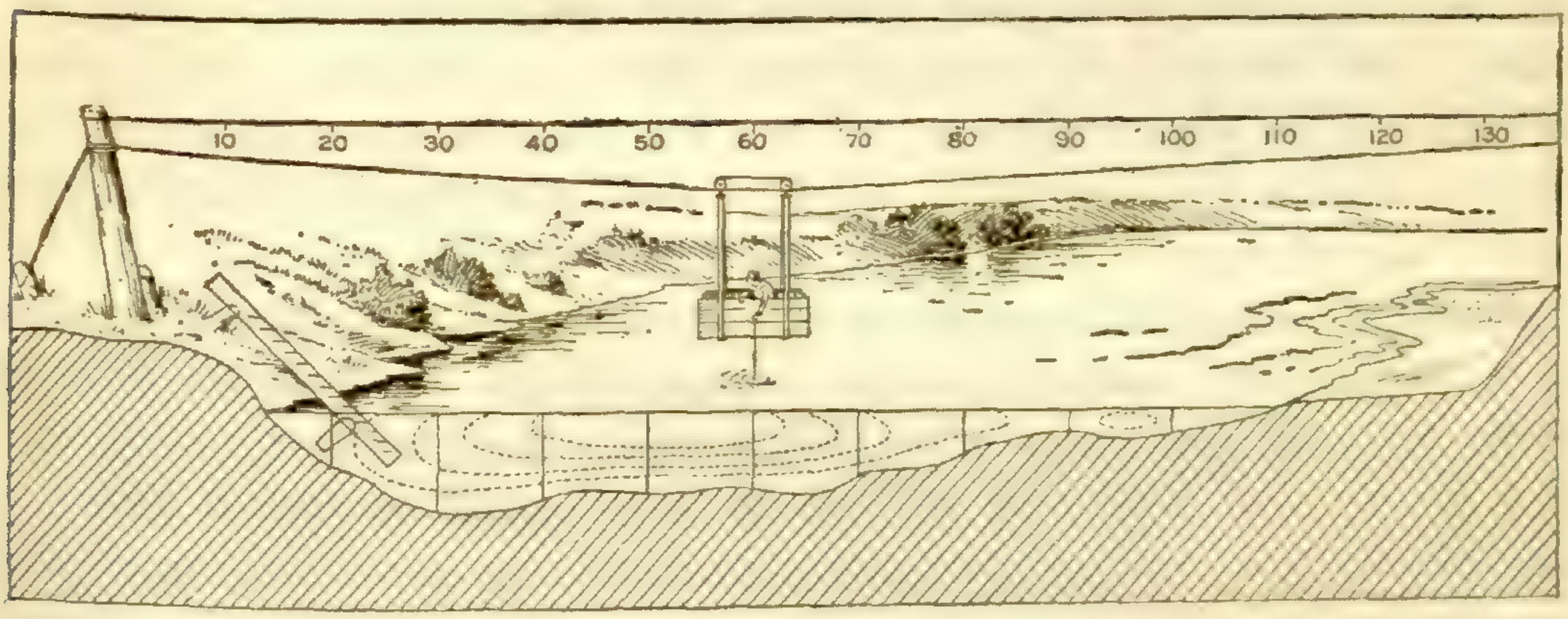

FIGURE 49.—Method of measuring the flow of a river at a cable station. The view shows the section of the river and the car, gage, and other apparatus.

the stream is at the stage at which the measurement is made.

Large rivers or even small streams at their flood stage can not be measured by wading, on account not only of the depth but of the swiftness of the stream, which may make it almost impossible to stand against the current, so that it may be necessary to work from a bridge or to span the stream with a cable from which the meter is suspended and held at the proper depth in the water by means of lead weights. To swing a meter weighted with 20 or 30 pounds of lead for several hours in measuring a swift river from a bridge is a form of exercise that is a sure cure for insomnia. If there is no bridge at the gaging station, the stream must be spanned with a cable, and the engineer must work from a car swung beneath it, as shown in figure 49. In this car he pulls himself along the cable to the points where measurements are to be made. A cable-car measurement is an even better cure for insomnia than a bridge measurement. In passing, it may be noted that if anything wrong happens to the current-meter equipment it always happens when the engineer is suspended in midstream while it is raining or while a wind is blowing what the loyal Westerner mildly terms "just a stiff breeze."

Discharge measurements are made at different stages of the water. Perhaps half a dozen will cover the range between high and low water. These measurements, when plotted on cross-section paper, define a curve known as the "rating curve" for the station. From this curve the discharge for any stage of water can be estimated, and the engineer can calculate with sufficient accuracy for most purposes the daily flow from the gage readings furnished by the local observer.

If a river carried the same quantity of water each year it would be necessary only to maintain a gaging station at a particular place for a year, but as the flow varies widely from year to year it is necessary to maintain the stations for several years in order to determine the flow not only for an average year but for the wet and the dry years.

flows in these washes, but occasionally heavy rains or cloudbursts in the foothills send down a torrent that sweeps like a wall of water down the valley. The flood crumbles the banks of soft shale and clay, sweeps away bridges, uproots orchards and crops, and produces general devastation, although the rain that caused all this destruction may have been limited entirely to the foothill belt, none having fallen where the damage is done.

Loma.

Elevation 4,525 feet.
Population 708.*
Denver 466 miles.

Near the village of Loma the river, which has been in sight in many places on the south (left) at the foot of the upturned red sandstone, turns to the left and enters a canyon in the Gunnison formation. The High Line canal of the Reclamation Service has been constructed farther west than Loma and provides for the irrigation of 35,000 acres by the gravity system and 10,000 acres by the pumping system. North of Loma several of the projecting points of the Book Cliffs are colored red and give to this part of the cliffs a different color tone from that which they have farther east. The red color is due to the burning of one or more coal beds and the consequent baking and reddening of the adjacent rocks. The Book Cliffs seem to have lost the abruptness that characterizes them near Palisade. They are broken into a number of terraces, which rise one above another until the height of the whole mass is about equal to that of the cliffs farther east.

Although the river has entered the canyon in the pink rocks on the south, the valley formed by the erosion of the shale and followed by the railroad continues in a northwesterly direction. Some of the land is irrigated, but most of it is in its original condition and the general aspect of the country is not particularly promising until the traveler reaches Mack, the terminus of the Uintah Railway, a narrow-gage line that leads from Mack northwestward over the Book Cliffs and down to Dragon and Watson, Utah. The region about Mack is barren and uninviting, but the grounds around the hotel built here by the Uintah Railway form an oasis in the desert. This quaint bungalow is embowered in trees, and on a hot day it makes an inviting resting place for those who have been exposed to the scorching sun or who are changing from one road to the other.

Mack.

Elevation 4,540 feet.
Denver 469 miles.

The Uintah Railway is used largely to transport gilsonite from the mines in the vicinity of Watson, Utah, to the main line of the Denver & Rio Grande Western Railroad, for shipment to market. The veins and mines are described below by D. E. Winchester.[58]

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[58] Gilsonite is a hard but brittle black hydrocarbon with a glassy luster, which occurs in great vertical veins at many places in northeastern Utah and is being mined extensively near Watson and Bonanza. The pure gilsonite is

Although the shale which forms the valley that the traveler has been following from Grand Junction to this place, if he came over the main line, or from Montrose, if he came over the narrow-gage line, continues along the foot of the Book Cliffs to the region beyond Green River in Utah, the railroad does not follow it because near the State line it ceases to form a valley and the outcrop is rough and is broken by stream valleys that cross it. In order to avoid this rough country the railroad turns to the south (left) soon after leaving Mack and follows the river through Ruby Canyon for a distance of more than 18 miles. The gap in the ridge through which the railroad reaches the river can be seen on the left from the station.

Half a mile beyond Mack the railroad swings sharply to the south (left) and leaves the shale valley. It cuts through the sandstone rim that bounds the valley on the south nearly at right angles, disclosing the sandstones and variegated shale beds that underlie the dark shale (Mancos) of the main valley. The first sandstone to be seen is the Dakota, the lowermost formation of the Upper Cretaceous. Underlying the Dakota is the McElmo formation, equivalent to the upper part of the Gunnison formation, which has already been seen at a number of places. The McElmo formation has everywhere about the same character and when once recognized is easily identified wherever it is seen. It includes an upper member 150 feet thick—the one that is first seen after leaving Mack—composed of variegated shale and sandstone, which on account of its relative softness weathers back into gentle slopes. The underlying member is about 60 feet thick and consists mainly of sandstone, which is more resistant to weathering than either the overlying or the underlying shale and therefore stands out and makes terraces or benches on the hillsides. The sandstone is in turn underlain by a gray clay or shale, which has a thickness of about 100 feet. These rocks form the canyon walls for a distance of about 2 miles, but they are so soft that in no place are the walls very steep. Owing to the red and green tints, the color effect is rather pleasing. but it soon becomes monotonous, and some other color or larger masses of color would make a welcome change.

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easily mined with a hand pick and is placed in large bags to be hoisted to the surface ready for shipment to market. The veins are rarely more than 10 feet in width, but they extend to unknown depths and in some places have been mined to a depth of 200 to 300 feet below the surface. The miners take special precautions to prevent fire, for the gilsonite dust is extremely explosive. No artificial lights are used in the mines, even at great depths.

The entire gilsonite output of Utah (about 20,000 tons annually) is hauled over the narrow-gage Uintah Railway to Mack, where it is reloaded to the larger cars of the Denver & Rio Grande Western Railroad.

Gilsonite is extensively used in the manufacture of paints, varnishes, roofing materials, and rubber substitutes.

The structure or attitude of the beds in this part of the canyon is simple. The rocks rise abruptly at an angle of 30° from the shale valley on the north, but they soon flatten and for some distance lie flat or dip slightly toward the southwest. The railroad follows the valley of Salt Creek, but the bends of the creek are so short that they do not everywhere accommodate the railroad, and about a mile from Mack it cuts through one of the small bends by a short tunnel in the sandstone member of the McElmo.

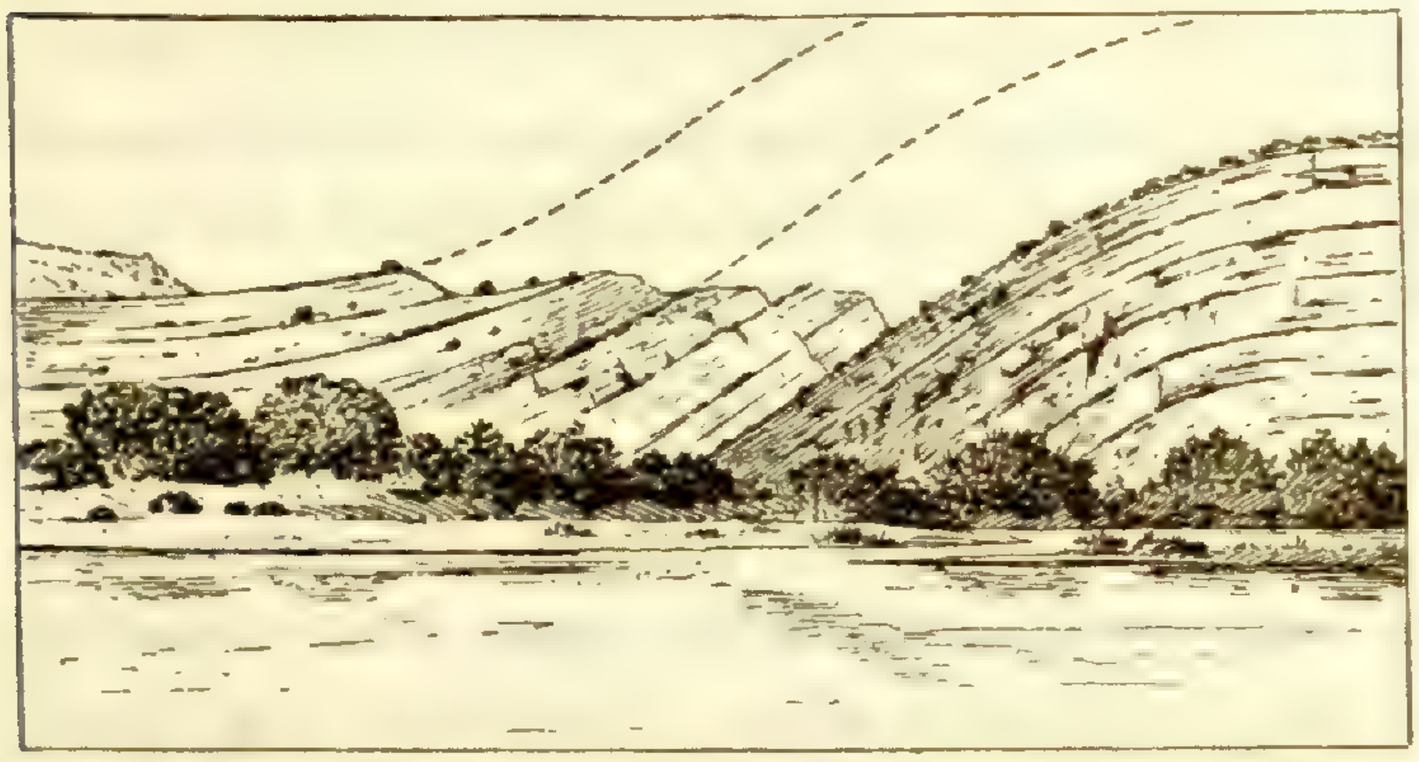

FIGURE 50.—Short fold in massive sandstone (on the left of the westbound train) opposite Ruby siding, below Mack.

About a quarter of a mile beyond milepost 472 the railroad reaches the river, and from this point to Westwater it follows the right bank. The canyon, because of its red color, is generally called Ruby Canyon, but the most strongly marked red rocks do not appear until the traveler is about half a mile below the siding named Ruby. Here the massive sandstone that underlies the McElmo comes up suddenly in a great fold,[59] which may be seen on the opposite side of the river. (See fig. 50.) The uppermost bed in this fold is not red but nearly white, although generally it is stained pink from the overlying McElmo shale. The white sandstone (La Plata) has a thickness of nearly 100 feet, but below it is a bed of somewhat softer sandstone, which is deep red. The fold is very short but steep, the beds having a dip of about 45°. The angle of dip decreases, however, and in a very short distance the beds lie practically flat.

Ruby.

Elevation 4,407 feet.
Denver 473 miles.

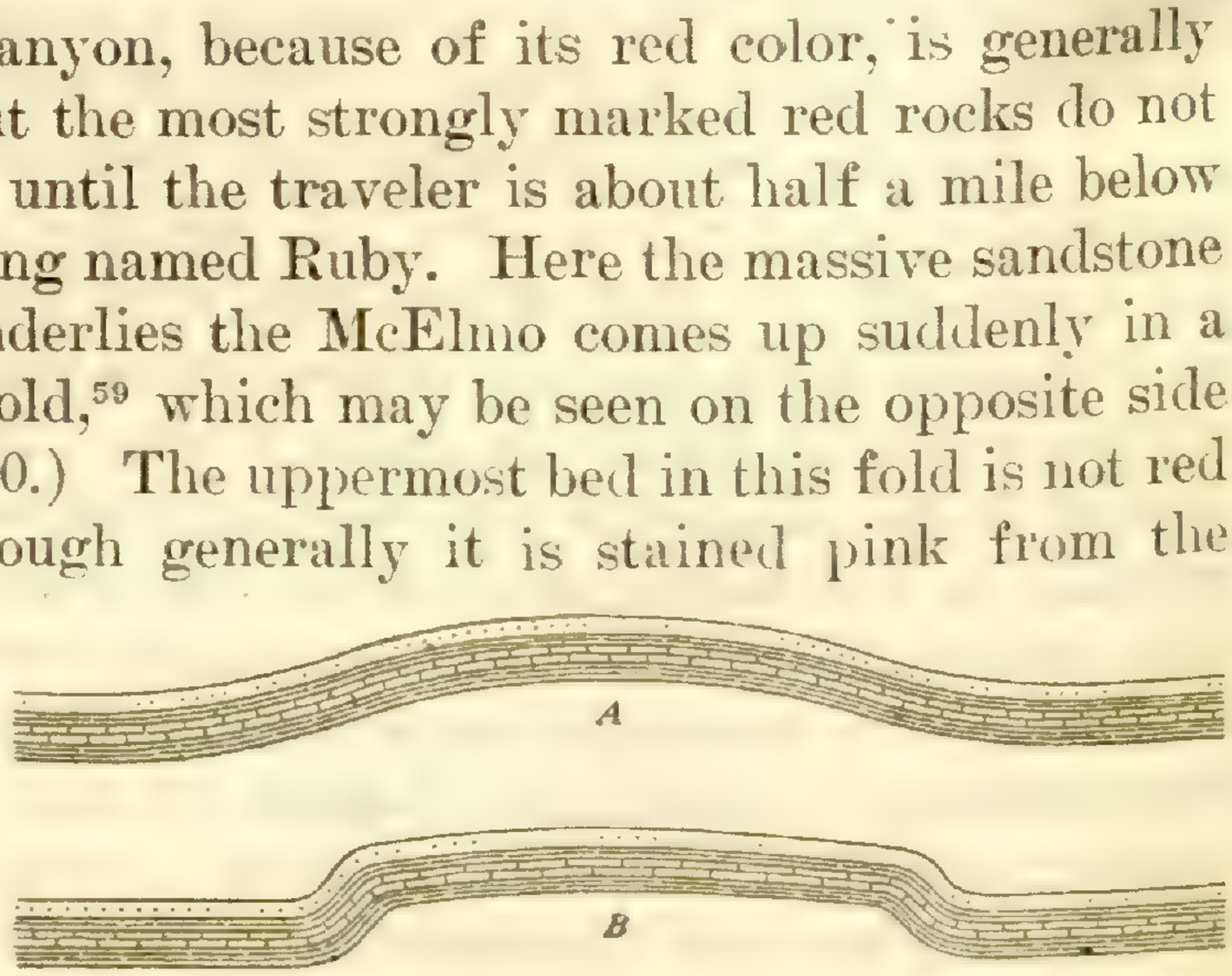

FIGURE 51.—Different types of anticlines.

[59] The rock folds in the plateau district of Colorado and Utah are different from those which the traveler has seen in the Rocky Mountain region. Generally anticlines are great upward bulges in the rocks, in which the beds are nearly equally curved in all parts, as shown in *A*, figure 51. In the plateau region the general effect of an anticline may be the same, but the location and form of the fold may be very different, as shown in *B*. The beds are very strongly folded on the flanks of the anticline, but the area affected by the fold is very narrow. The traveler may see many such folds as that shown in *B* before he reaches Salt Lake City.

The sandstone which rises above water level just below Ruby siding is massive—that is, it is almost without bedding planes or lines of separation—and consequently it makes a canyon which has smooth, nearly vertical walls (Pl. LXXIX). The color, except in the uppermost layer, about 100 feet thick, is decidedly red, so that in general the canyon walls are a bright red, and the name Ruby is quite appropriate. A close look at the sandstone will show that it is not evenly banded like many of the sandstones in the region to the east, but that the marks along the edges of the beds—which indicate the form of the layers in which the sand was laid down—dip at all angles, or rather are generally curved, showing that the sand was carried into the place where it was deposited by strong currents of air or water, which cut away much of the sand that had been formerly laid down and in its place deposited layer after layer in a curved position. This process is termed cross-bedding, and an extreme example of it is shown in Plate LXXVI, *C* (p. 179). These beds were all laid down on the land, or at least no marine fossils have been found in them.

The graceful swing of the river from bend to bend and the corresponding curves in the smooth massive walls of the canyon are well shown in Plate LXXIX.

The rocks rise gently downstream, and near milepost 477 the canyon walls have a height of about 300 feet. Just a little below this point dark granite[60] appears in the bed of the river, and therefore 300 feet is about the full thickness of the sedimentary beds in this canyon. The granite is exposed on the crest of a small anticline or uplift, and in a few hundred yards it disappears. The upper surface of the granite is smooth and doubtless once formed the land surface upon which the sand was laid down.[61]

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[60] The crystalline rock that constitutes the foundation upon which western Colorado and eastern Utah have been built presents different phases from place to place; in one place it may be a true granite, in another a gneiss, and in another a schist. As these phases grade into one another the exact character of the rock in all places can not easily be specified, and so it is here called granite because this term is in general sufficiently exact, and an attempt to differentiate the various kinds of crystalline rocks might be complicated.

[61] In the canyon of Colorado River just above Glenwood Springs the same granite or gneiss is exposed, and the stream has cut its channel in this rock to a depth of 1,000 feet. The quartzites, limestone (Ouray), and variegated Carboniferous rocks above the limestone, extending from the canyon just mentioned almost as far as Wolcott, are not found in Ruby Canyon. As many of these formations are of marine origin it seems probable that they were originally deposited over all this region but that later the sea bottom was uplifted so as to form land and then the streams and the weather slowly cut the rocks away until in places the formations mentioned were removed before the red sands were laid

Although the river has been the principal agent in carving Ruby Canyon it has not done all the work, for the moisture in the atmosphere and the sand blown by the winds are very active in wearing away the rocks. The results of the work of both of these agents may be seen at many places. The moisture in the atmosphere dissolves the cementing material that binds the grains of sand together, and the wind mechanically removes the loosened grains. These agencies acting together eat out cavities in the canyon wall, most of them small, though here and there one is excavated into an immense alcove having an arched roof. Wind-driven sand cuts the hard rock like a sand blast, and as the texture of the rocks differs from point to point the cutting has produced grotesque, fantastic forms. At some places the sand blast has cut the finest fretwork; at others it has simply rounded off projecting points of rock so that they stand out as great domes or circular minarets. Many such features cap the solid canyon wall, but they are so far above the track that the traveler can see them only as he looks ahead at some projecting spur or back at the disappearing view. At one place a group of columns on a salient point on the canyon wall resembles a procession of Egyptian figures, as shown in the ornamentation of their temples, and consequently these are known as "The Egyptian Priests."

Beyond the place where the granite appears in the river bed the rocks dip gently downstream as far as milepost 479, where they are again elevated in a fold similar to that which has exposed the red sandstone just below Ruby. This fold is not so apparent from the train as that just mentioned, but by looking ahead from a point near milepost 479 the traveler may see it in the canyon wall on the right, and he may note traces on the projecting point on the opposite side. This fold raises the sandstone so high that the granite again appears in the river bed, rising at least 20 feet above ordinary water level and being visible from the train for about a mile. The river has had much greater difficulty in cutting the granite than in cutting the sandstone; the sandstone has been entirely removed, but the granite forms a very effectual barrier in which the stream has been able to cut only narrow channels, through which the water boils and tumbles, so that the rock is scoured and polished by the sand that the water carries over it. Pebbles accumulate in hollows of the rock and soon grind out deep holes where they are given a rotary motion by the current. Such holes, which are known as "potholes," are abundant in the granite in this canyon.

In places the massive sandstone overhangs the railroad, as shown in Plate LXXX, *A*, and the beetling cliffs afford ideal sites for the

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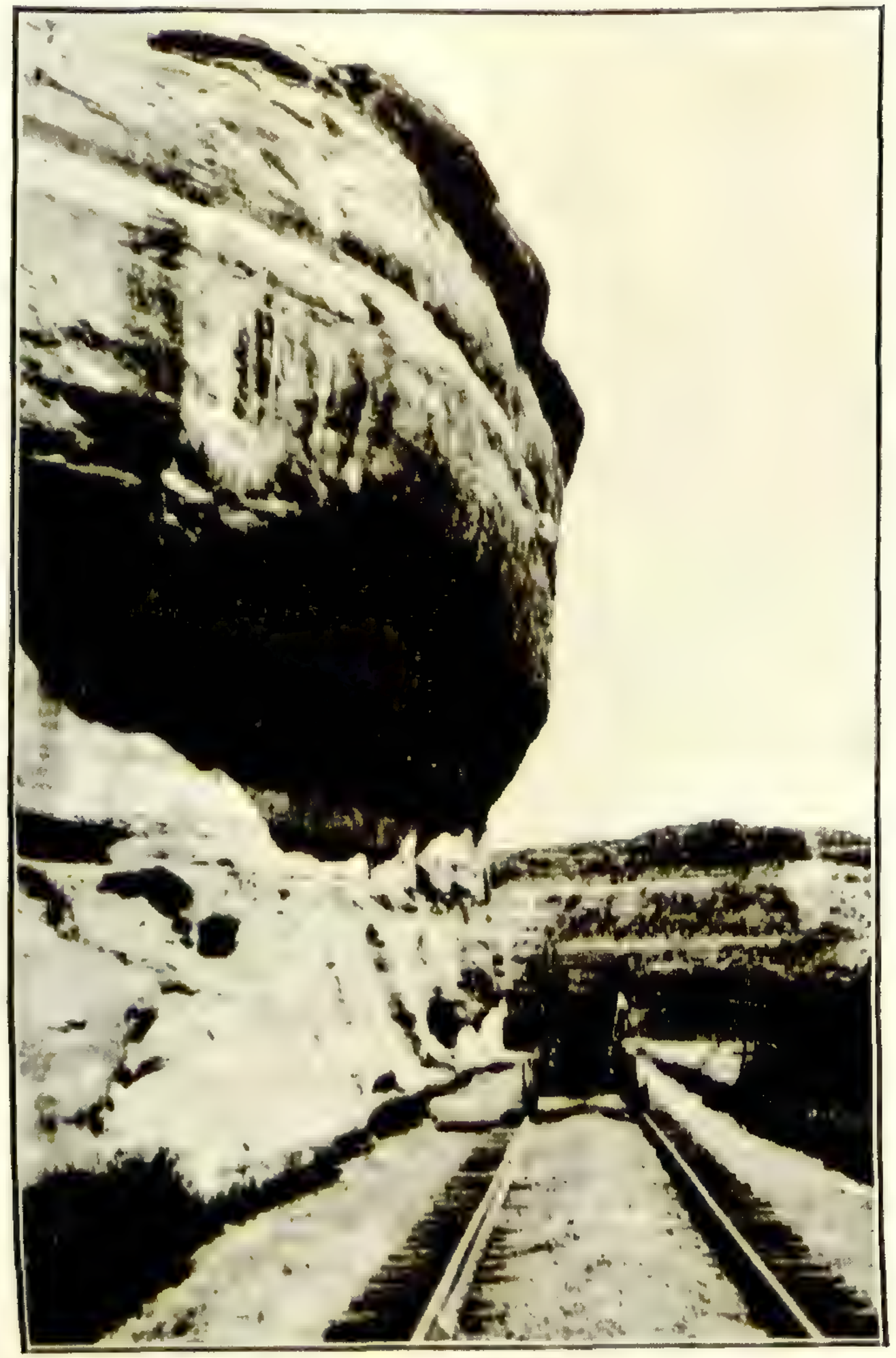
down, although in other places only a part of them were removed. Hence at different localities different formations rest on the granite.

RUBY CANYON.

This canyon takes its name from the deep-red color of the rocks. Its walls are generally smooth, and in many places they are vertical from top to bottom. The massive cliffs curve gracefully in conformity with the great sweeps of the river around the projecting spurs, first on one side and then on the other side of the canyon. Photograph furnished by the Denver & Rio Grande Western Railroad.



A. OVERHANGING WALLS OF RUBY CANYON.

The massive red sandstone makes very imposing walls in Ruby Canyon. In places it nearly overhangs the track. Photograph by Marius R. Campbell.

B. THICK COAL BED.

Old prospect entry on 15 foot coal bed near Helper. These thick beds of good coal will doubtless be greatly developed. Photograph by Frank R. Clark.

C. COLORADO-UTAH STATE LINE.

The boundary line between Colorado and Utah is well marked in Ruby Canyon. Photograph by Marius R. Campbell.

mud dwellings of swallows, which circle about such places in countless numbers. In other places the rocks assume fantastic forms, especially on projecting points between the sharp bends of the stream or between tributary canyons, as if mighty buttresses were necessary to support the vertical walls, but a general and solid massiveness and the nearly vertical character of the walls make a stronger impression upon the mind of the traveler than any other feature.

The granite disappears beneath the river bed near milepost 481, and the rocks below that point dip gently southwestward and the height of the walls gradually diminishes to the place where the canyon is crossed by the boundary line between Colorado and Utah. The boundary is marked by a monument at the left of the track and by a line painted on the cliff at the right, with "Colorado" on the east of it and "Utah" on the west. (See Pl. LXXX, *C*.) The canyon walls here are only about 200 feet high, and they decrease in height and impressiveness until the red sandstone passes below the level of the track near the point where the railroad crosses Bitter Creek, close to milepost 488.

Utaline, Colo.

Elevation 4,344 feet.
Denver 484 miles.

Below Bitter Creek the walls of the canyon are made up of the softer beds of the McElmo formation, and they recede from the river, leaving a broad valley which at one time was selected as the site of a town that was to be named Westwater, but unfortunately for the founder his dreams were not realized, and the town to-day consists only of section houses, a water tank, and one or two farms. At this point the Denver & Rio Grande Western leaves Colorado River, which the traveler will see no more on this journey. By looking to the left (downstream), however, he will see that the rocks rise again and that the canyon assumes large proportions. Indeed, its vertical walls seem to be even more pronounced than those that mark its course above Westwater.

Westwater, Utah.

Elevation 4,340 feet.
Population 94.
Denver 488 miles.

About a mile from Westwater the railroad crosses Cottonwood Creek, which heads in the foothills of the Book Cliffs. The road extends up one of the branches of this creek to the divide between it and some other small streams on the west. In climbing, however, the traveler sees the same rocks at the level of the track, for the rocks rise toward the west in a great fold that brings up the red sandstone again below Westwater. So, when the traveler reaches the siding of Cottonwood, which is at the summit, the beds which he sees are of the same age as those which he saw at the crossing of Cottonwood Creek, 4 miles to the east.

Cottonwood.

Elevation 4,532 feet.
Denver 493 miles.

After journeying through the canyon for about 20 miles the traveler will probably be glad to leave it and to gain the upland, where he may see something more than rugged rock walls and muddy river. If the vegetation on the upland is not parched and dried by the summer's heat, the sego lily, Utah's floral emblem (Pl. LXXXI), may be seen here and there lifting its delicate head, though it stands so close to the ground that it is difficult to identify from the moving train. The wide expanse of upland also enables one to see the larger features of the surrounding landscape. One of the first objects to catch the eye on the left is a distant group of mountain peaks—the La Sal Mountains—whose highest point reaches an altitude of about 13,000 feet. One unaccustomed to judging distances in the clear air of an arid country can not say whether these mountains when first seen are 10 or 50 miles away, but careful measurement has shown that the nearest peak is about 30 miles distant. This mountain group was formed by the uplifting of the rocks in a great domelike mass, and if the light is just right the traveler may see the great cliff-like wall of red sandstone, with which he is now becoming familiar, on the east side of the mountains, where it has been uptilted by the movement. This group of mountains will be in sight for some time, and a little farther west it can be seen to better advantage.

The railroad winds about in the low hills of the McElmo formation, which in places are somewhat picturesque on account of the great variety of their colors, but in general the outlook is not particularly pleasing. The scene, however, may be of great interest to one not familiar with it, for it gives him a good idea of the utter barrenness of a region where the rainfall is as scanty as it is in Grand County, Utah. In places the rocks are very dark, and the traveler may think that they have been baked to this dark color by volcanic fires and that many of the rock fragments are pieces of lava. The geologist, however, knows that the rocks of this region are not volcanic. In fact, all the rocks composing the McElmo and Gunnison formations were laid down as sediments in lakes or ponds or in the beds of streams, and the dark rocks are only those that contain considerable iron, or those that have been coated by so-called "desert varnish," a dark substance, probably in large part manganese, which tends to cover all exposed rocks in the desert region and to give them a black color. It is from the McElmo and La Plata formations or their equivalent, the Gunnison formation,[62] that most of the ores

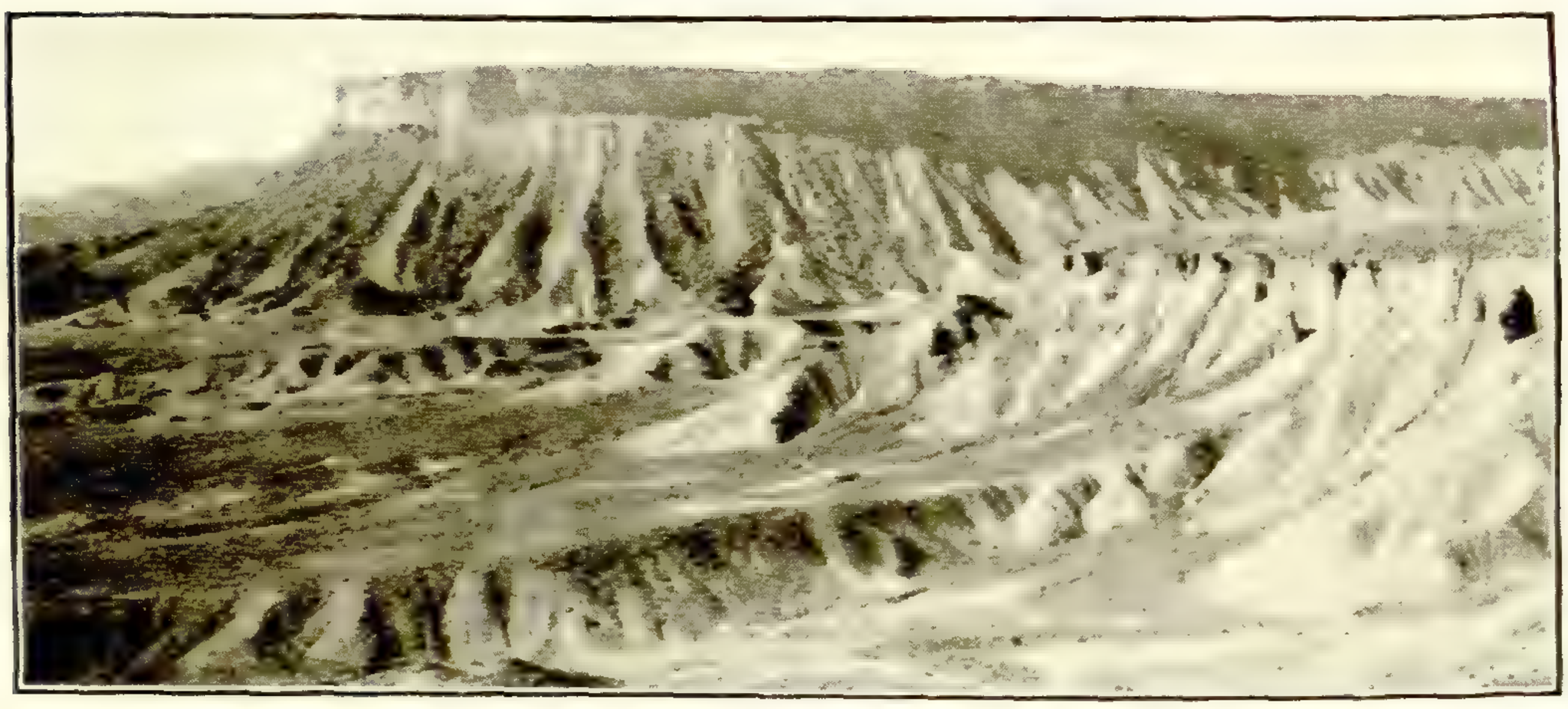
[62] In the region between Denver and Salt Lake City the formation immediately beneath the Dakota sandstone bears a number of names, which are exceedingly confusing to anyone who is unfamiliar with the rocks and their relations. Thus along the Front Range the Morrison is a well-marked formation of variegated shale and sandstone whose age is uppermost Jurassic or lowermost Cretaceous. It is a fresh-water formation and con-

STATE FLOWER OF UTAH.

This delicate flower is commonly known as the Sego lily, but by botanists it is called Calochortus nuttallii. It grows in abundance on the higher lands of the State and is one of the most beautiful of the wild flowers. Photograph by Shiplers, Salt Lake City.

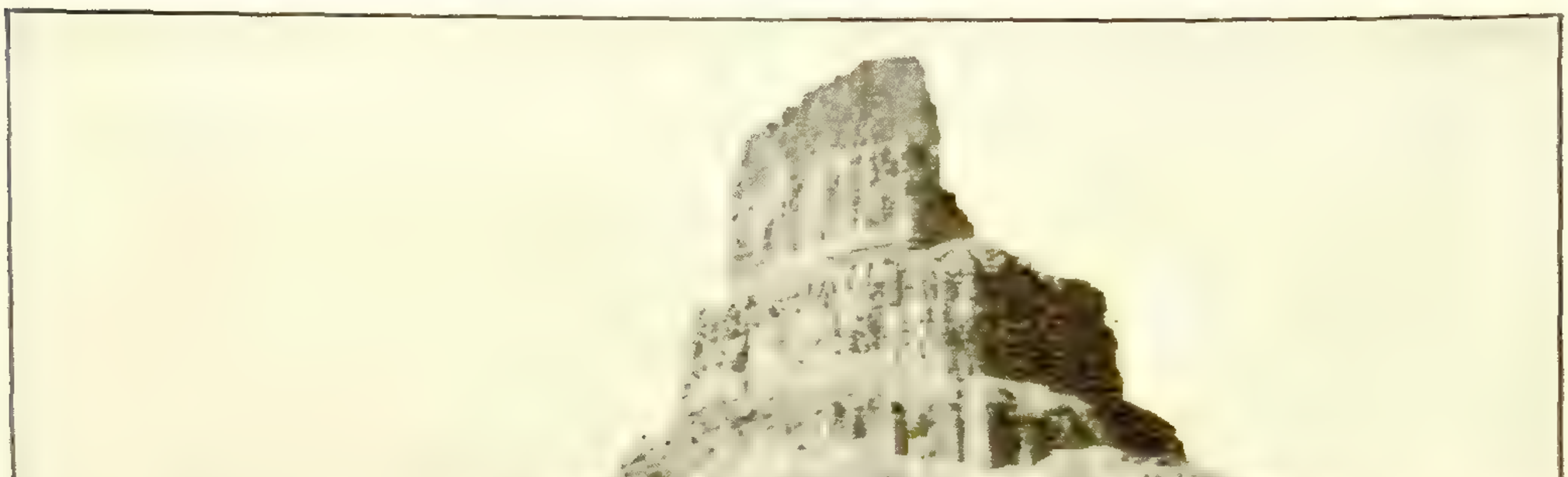
A. PLATEAU NEAR MOAB.

Some of the wonderful towers and walls that may be seen on the left from the railroad. There are no curves in this landscape, only straight lines and angles. Some of the valleys hidden in these rugged plateaus are very beautiful but difficult of access. Photograph by Whitman Cross.



B. SHALE BADLANDS AT FOOT OF BOOK CLIFFS.

Between Cisco and Thompson, Utah, the railroad winds about in shale badlands similar to those shown in this view. They are nearly barren of vegetation and to many persons seem desolate, but to the lover of nature they are wonderful exhibitions of the delicate carving that is going on during every shower. Photograph by G. B. Richardson.



C. GUNNISON BUTTE.

A prominent isolated butte on the bank of Green River, a few miles above the town of Green River. The butte was named in honor of Capt. Gunnison, who crossed the river at this place in 1853 while surveying for the Government a route for a Pacific railroad. Photograph by M. O. Leighton.

of radium are obtained, and one of the most productive districts lies in Paradox Valley, Colo., 15 or 20 miles east of the La Sal Mountains.

The low hills of McElmo rocks seem endless, but finally they are passed, and at milepost 501 the railroad cuts through the Dakota sandstone, which dips about 30° W. Next it enters the Mancos shale, which the traveler last saw at Mack, before he entered Ruby Canyon, and the features of the surface now become more subdued and softer, and he has a better opportunity to see what surrounds him. To the north he will see the familiar Book Cliffs, but they are so far away that their character is scarcely apparent. However, they swing to the south around the great anticlinal point through which Ruby Canyon is cut, and in 15 or 20 miles they will be so near the track that they can be clearly seen.

At the place where the railroad crosses the Dakota sandstone, at milepost 501, it is within a mile of the great bend which Colorado River makes to the northwest, but despite its nearness the river lies so deep in its canyon that it is not visible from the train. Three miles beyond this point is the village of Cisco, which is one of the largest shearing and shipping points in this great sheep-herding country. One unfamiliar with this region might think that there was little or no pasturage here for even a sheep, but when rain falls the country is green with grass, and even in times of drought there are forage plants that might not be noticed by the unaccustomed eye.

Cisco.

Elevation 4,375 feet.
Population 95.
Denver 504 miles.

After the train passes Cisco the La Sal Mountains are in plain sight, and the traveler may see the great red wall on the east and also

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tains the remains of immense reptiles (dinosaurs).

West of the mountains a similar assemblage of fresh-water sandstones and shales lies immediately beneath the Dakota. Undoubtedly this formation is in part equivalent to the Morrison, but as it is supposed to contain lower beds than the Morrison it can not be considered exactly equivalent, so it was called the Gunnison formation.

Later, in working out the succession of formations in the San Juan Mountains in southwestern Colorado, Cross found that beds nearly equivalent to the Gunnison were greatly expanded, especially in the lower part, and he felt compelled to introduce the term McElmo for rocks of nearly the same age as the Morrison, and the term La Plata for a massive white underlying sandstone. The La Plata sandstone should perhaps be included in the Gunnison. Recent work has extended the names McElmo and La Plata northwest to Greenriver, Utah.

In spite of this confusion it seems best here to use the three terms, so the name McElmo is applied on sheets 7 and 8, although Gunnison was used on sheet 6 for rocks of about the same age. The reader should therefore remember that the Morrison, Gunnison, and McElmo include rocks that may be equivalent in age.

the place where it is upturned and cut by the river between the railroad and the mountain. As seen from the train the country to the right of the La Sal Mountains is exceedingly rough and rugged, being cut into great canyons with vertical sides or left in giant blocks, also with vertical sides. In fact, the traveler is now approaching a region in which the expression of the topography is different from anything that he has yet seen, unless he is already acquainted with the country that was called by Powell the "Canyon lands." In this region Hogarth's "line of beauty" is unknown. The slopes of the hills and mountains do not show gracefully curved lines from summits to bases, but each slope forms a straight line and unites with its neighbor in an angle and not a curve. The valleys are all canyons, which either have vertical sides or sides composed of straight lines, and the intervening spurs are mesas with flat tops as

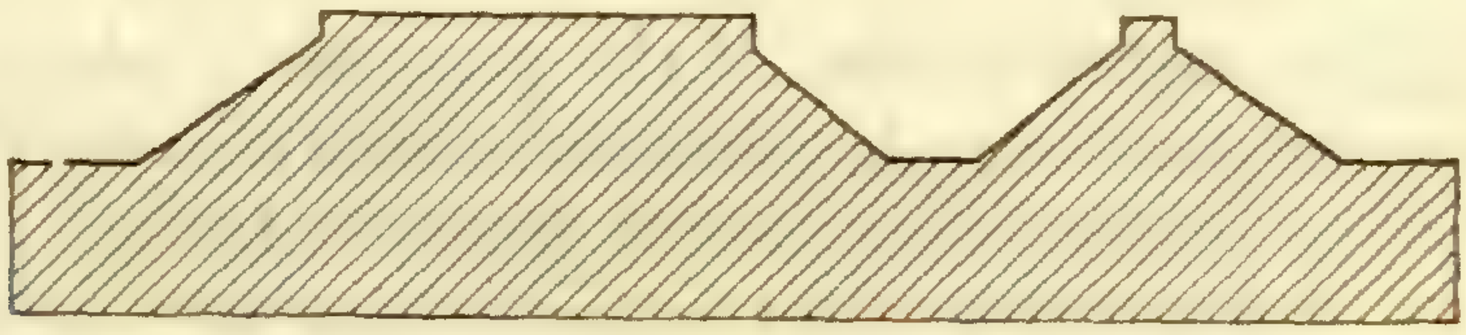

FIGURE 52.—Angular profiles of the Plateau province.

shown in figure 52. A glance at the country on the right of the La Sal Mountains will show some of the angularity mentioned. This characteristic feature of the land forms is illustrated in Plate LXXXII, *A*, which is a view taken near Moab. It also shows some of the slender towers of rock which the traveler may see from the train.

Although the La Sal Mountains have attracted much attention, another group of mountains, which are even more interesting, are slowly appearing above the horizon, far to the southwest. Where first seen, in the vicinity of Cisco, these mountains, named the Henry Mountains for Joseph Henry, the first Secretary of the Smithsonian Institution at Washington, are fully 100 miles distant. They are divided into three groups—the larger group at the north and two isolated peaks farther south.[63] These mountains lie on the west side of Colorado River, which in this region flows in a canyon 1,000 feet deep.

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[63] The study of the Henry Mountains in 1876 by G. K. Gilbert led to the discovery of a new type of mountain, which is indirectly of volcanic origin but is not a volcano. It is now known that the La Sal Mountains and many other similar groups in the Plateau province belong to the same class. Gilbert found that the peaks of the Henry Mountains are composed largely of hardened lava, which, when it was in a molten state, instead of ascending to the surface through some fissure in the rocks and then pouring out over the surrounding country as a lava flow, welled up in the earth's crust until it lifted the covering rocks and forced them up in a great dome. As

GEOLOGIC AND TOPOGRAPHIC MAP
OF THE
RIO GRANDE ROUTE
From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

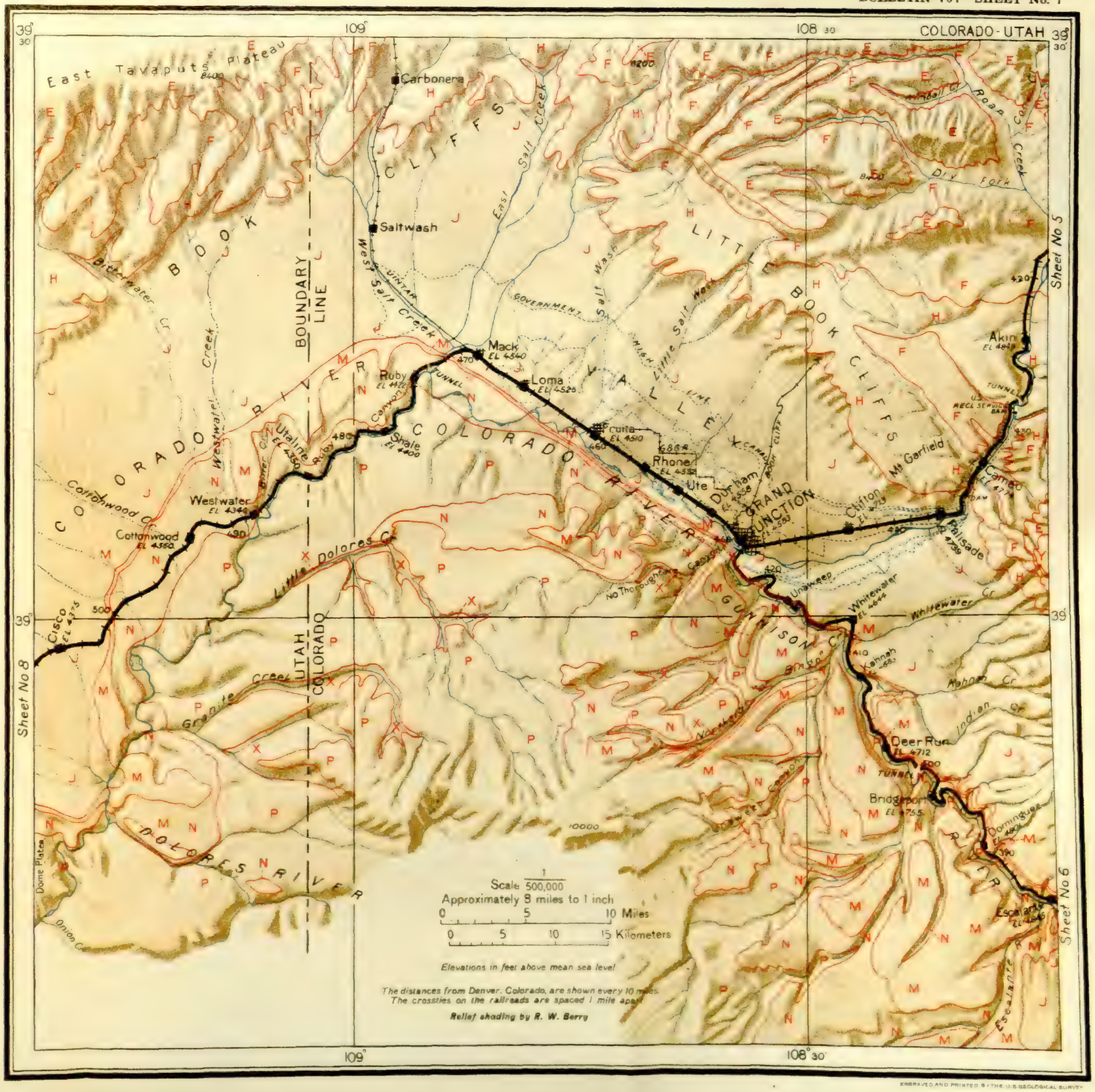
PREPARED UNDER THE DIRECTION OF
GEORGE OTIS SMITH, DIRECTOR

DAVID WHITE, Chief Geologist
M. R. CAMPBELL, Geologist
C. H. BIRDSEYE, Chief Topographic Engineer
A. C. ROBERTS, Topographer

1922

EXPLANATION

		Age	Thickness in feet
E	White shale and sandstone (Green River formation)	Tertiary (*Eocene*)	2,600
F	Red shale and sandstone (Wasatch formation)		3,400
H	Sandstone, shale, and coal beds (Mesaverde formation)	Upper Cretaceous	2,200
J	Dark marine shale (Mancos shale)		3,000
M	Brown sandstone (Dakota sandstone)		50
N	Variegated shale and sandstone (McElmo formation and La Plata sandstone, equivalent to Gunnison formation)	Cretaceous (?) and Jurassic	310
P	White sandstone at top and brick-red massive sandstone below	Triassic	350
X	Granite	Pre-Cambrian	
Y	Lava flow	Tertiary	



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Beyond Cisco the railroad curves here and there over the shale upland, steadily approaching the foot of the Book Cliffs. (See sheet S, p. 210.) As it nears the cliffs it seems to be lost in a maze of small shale hills, as shown in Plate LXXXII, *B*, but in places one may catch glimpses through them of the ragged front of the cliffs. Viewed from a distance the Book Cliffs look like a regular mountain front, but viewed near by they are seen to be made up of a series of terraces or benches, each bench being formed by some hard bed of sandstone more resistant to erosion than the beds above or below. Each bench is cut by streams into a number of salients, or teeth, which project far beyond the main mass of the cliffs. Behind and above the lowest row of salients there may be a second row, formed

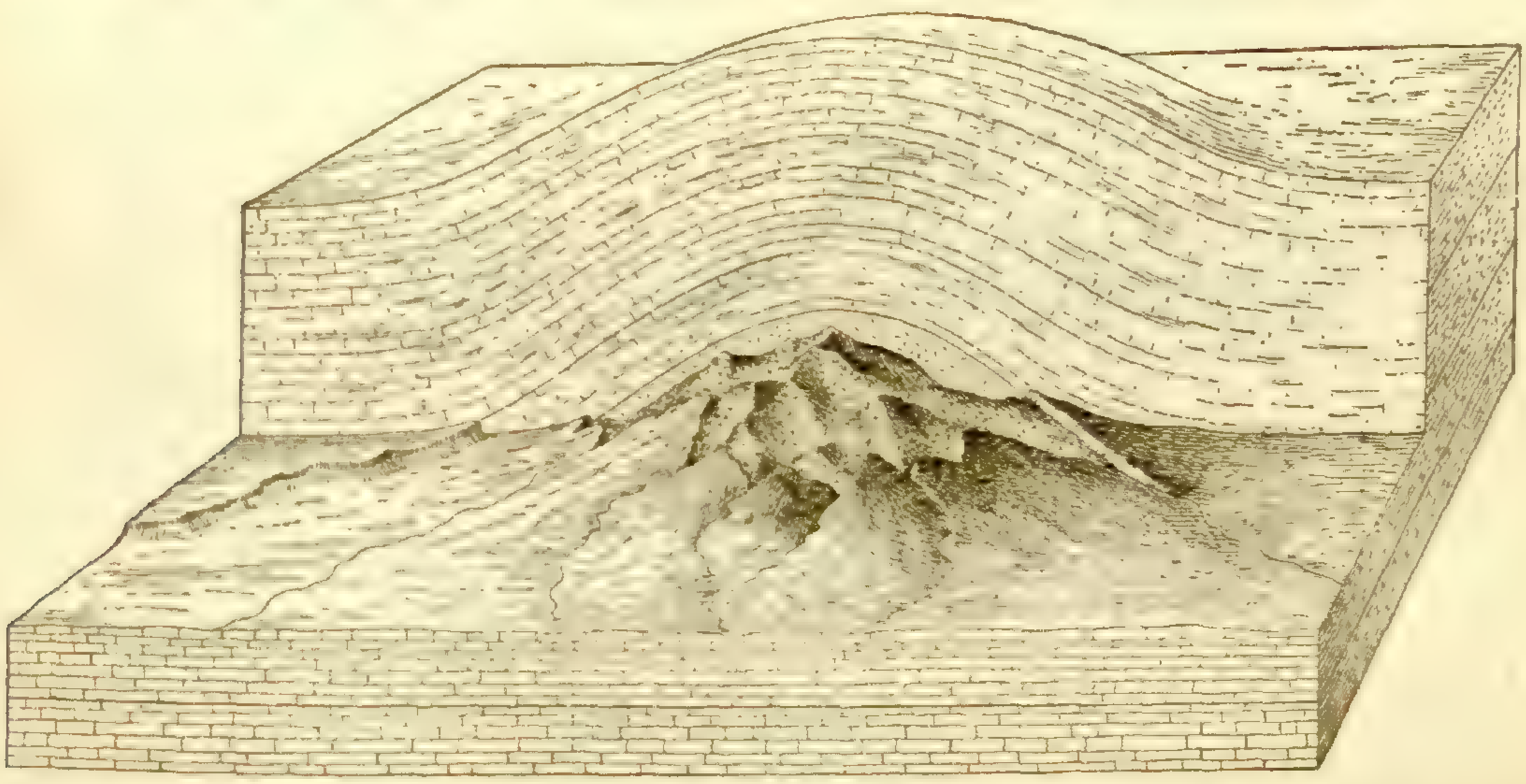


FIGURE 53.—Mountains carved from a laccolith. The block at the rear shows the former position of the sedimentary beds after they were forced upward by the intrusion of the lava.

by a similar hard bed, and in places there is a still higher row of salients, formed by a third hard bed. The resulting cliffs present a front that is very irregular in detail but very regular when viewed from a distance. A view along the front, showing the lower tier of salients, is given in figure 54. The lowest bench of the cliffs is formed by the lowest sandstone in the coal-bearing Mesaverde formation, and the slope below is composed of Mancos shale. This shale is very homogeneous in composition, and therefore on steep slopes it has been cut by many minute ravines, with a wealth of

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the hardened lava is more resistant than the surrounding rock, which has been worn away, it now stands up as a mountain or a mountain range.

On account of their peculiar method of formation Gilbert proposed for them the name "laccolite" (which was afterward changed to "laccolith"), meaning stone cistern. Laccoliths are not only recognized in the western country, but since they were described by Gilbert they have been recognized in almost every continent on the globe. A mountain group that has been carved from a laccolith is represented in figure 53.

detail that is amazing to one unaccustomed to the effects of the erosion of rocks in a semiarid region. What infinite pains Nature apparently takes even in carving one of these commonplace hill slopes! This carving is, indeed, a work of art comparable to that of the most skillful sculptor.

As the traveler goes westward he finds many shale ridges, which form the divides between parallel stream valleys that head in the Book Cliffs. These ridges have either flat tops or tops that slope regularly away from the front of the cliffs. The tops of the ridges stand from 80 to 100 feet above the general level of the plain and doubtless represent the surface of a former plain that stood that distance above the present surface. When that plain existed the streams

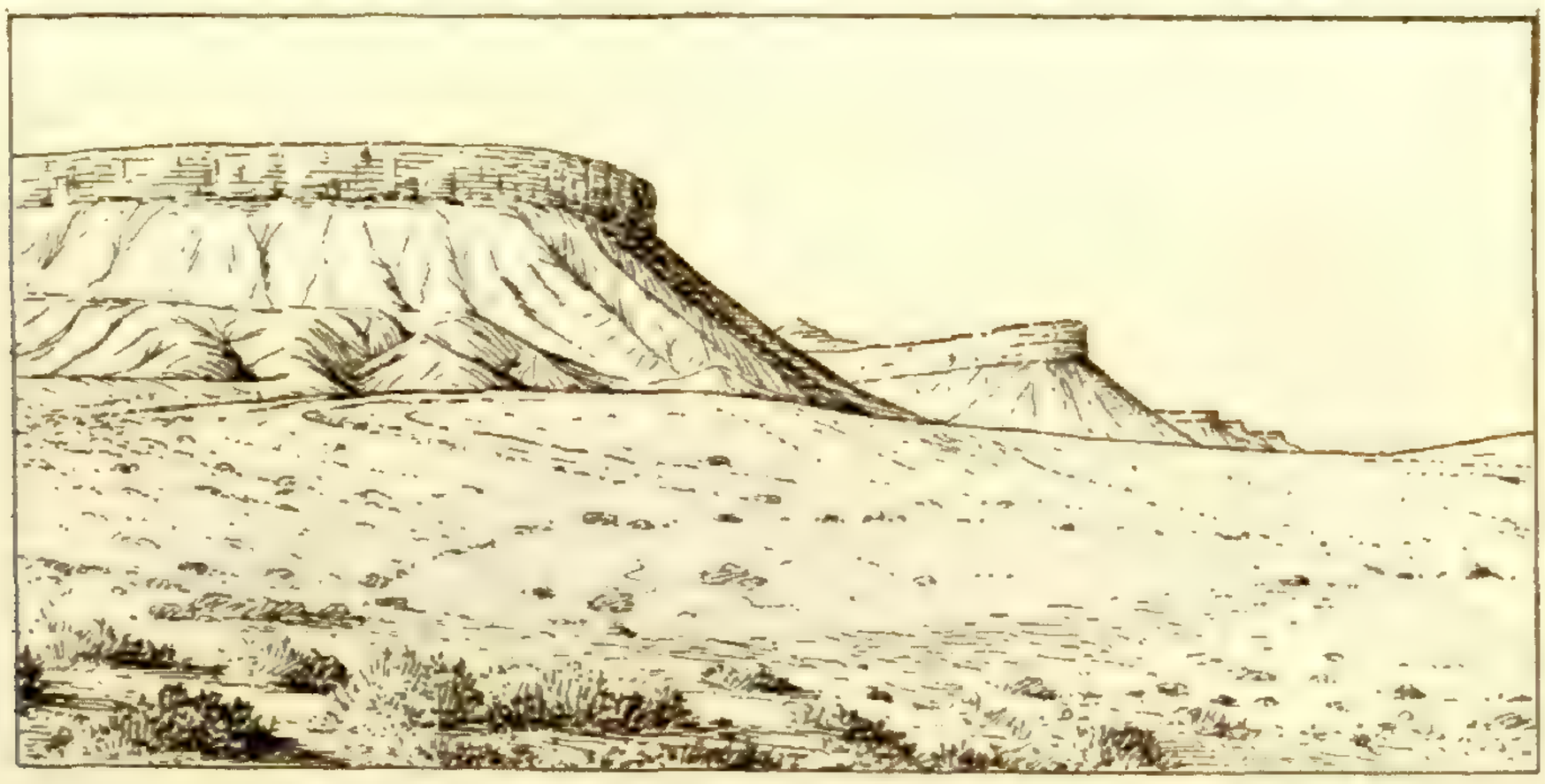

FIGURE 54.—Projecting point of the lower salients of the Book Cliffs. View looking east from Thompson, Utah.

could not cut deeper into it, and so the land was reduced to a gentle slope, but later the streams acquired greater cutting power and they have succeeded in eroding away most of the old plain except where it is best protected on the divides. What caused the increased cutting power of the streams is a difficult question to answer. It may have been an uplift of the country, or it may have been a change in climate by which the volume of water carried by the streams was greatly increased.

After the train has passed through cuts made in two or three of these shale ridges it reaches the village of Thompson, or, as it was formerly called, Thompson's Springs, a name applied to it because 5 miles up the canyon that opens at this place there are several springs which have been of great value. In a dry country all settlement except on the railroad depends on the presence of water, and in the early days Thompson's Springs were the chief source of supply for those who were forced to make the trip across this inhospitable country. When the railroad was built the springs were equally valuable as a source of supply for the locomo-

Thompson.

Elevation 5,160 feet.
Population 84.
Denver 528 miles.

tives, and water was piped from them to the line of the road. For a long time Thompson owed its prosperity to the water from these springs and to the business which it obtained as a supply and shipping point for the sheep owners in the region about Moab, an old Mormon town on Colorado River, 32 miles to the southeast.[64]

Coal mines have recently been opened 5 miles up the canyon, and the coal is brought to the railroad by a branch line. The coal is of good quality but not quite so valuable as that which is mined in the same formation farther west.

The many salients of the Book Cliffs show well from Thompson. By looking east or west along the front one can see point after point projecting from the plateau, as shown in figure 54. The intricate sculpture of the shale that composes the lower slopes of the cliffs is well shown about a mile west of Thompson. By contrast with the curves in the sculpture of the shale the angularity of the forms of the land impresses the traveler more and more as he gazes off to the southwest while he is passing over the plain just west of Thompson. Seen from this plain the profiles of the distant plateaus appear extremely angular and show no flowing curves. The landscape looks as if it had been formed by the hand of a giant who carved it with an axe, cutting here and there great angular chunks out of the flat-lying rocks. (See fig. 52, p. 198.)

A short distance west of a siding called Crescent the railroad cuts through a low ridge of shale, which is one of the remnants of the higher surface, and then begins the long descent to Green River. Immediately after cutting through the ridge the road turns to the north, and for about 10 miles it skirts the front of the Book Cliffs,

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[64] It was the settled determination of the early Mormon leaders to make their followers an agricultural people, for they knew that those who till the soil can much more easily be held in an organization like that of the Mormon Church and are less likely to wander away after "strange gods" than those who are engaged in other pursuits. A great empire was to be built, and its most secure foundation was a large and prosperous agricultural population.

The region in which they had settled and which they regarded as the "promised land" was much like that of Judea, in which the ancient Hebrews flourished, a land consisting in large part of deserts whose oases here and there afforded fine opportunities for a pastoral people. Soon after the first settlement of the valley of Great Salt Lake, in 1847, immigrants began pouring into Utah at the rate of several thousand a year, and the leaders had to find these oases and see that the newcomers were settled therein. In this work they were autocratic. Brigham Young directed the settlement of the valleys and even picked the families and the leaders who were to settle them. Nothing was left to chance. The proceeding was high-handed, but the results, as seen to-day, show that it was probably the best that could have been followed. Moab was one of these distant colonies, and others were established in southern Utah, Arizona, and California, as well as in more northern States.

running most of the way through badlands of soft shale that have been cut by rain and running water. It passes so near the cliffs that the traveler may see all the delicate fluting and also the sharp points of the salients which are protected by caps of heavy sandstone. Although the variety of details is infinite, the general similarity of the forms produced grows wearisome, and the traveler finally welcomes the emergence of the train from the badlands into the open plain, which leads down to Green River. This change occurs at a siding called Solitude, which indeed is rightly named. Here nothing is in sight but the endless expanse of plain covered with the stunted vegetation of the desert on the one side and the equally endless badlands on the other. To the eye of the sheep herder, however, this region is not desolate, for it affords fine feeding ground for his sheep. The impression of it, then, depends on the point of view; what the stranger sees as desolation no words can describe one familiar with the scene views without aversion and accepts at its real worth.

Immediately after the train rounds the curve beyond Solitude the town of Greenriver comes in sight, although it is almost 12 miles distant. At least the green trees in and surrounding the town can be seen, but they are nearly straight ahead and the traveler may have difficulty in locating them.

As the train passes down this even slope much of the surrounding landscape is spread out before the traveler. The Book Cliffs on the right swing far to the north in a great reentrant which Green River has cut in their generally even front. Across the river there is a strong salient, which is known as the Beckwith Plateau, named for Lieut. Beckwith, who was associated with Capt. Gunnison in his survey of this route for a Pacific railroad and who crossed Green River September 30, 1853. Capt. Gunnison lost his life in an encounter with a band of Indians after he had crossed the Wasatch Plateau, and Lieut. Beckwith prepared the report of the exploration. The most attractive features in the landscape are the wonderful tablelands and the peaks resembling ruined cities, which can be seen far across the river in the north end of what is known as the San Rafael Swell. This region is described in greater detail on pages 207–208.

As the traveler descends the smooth shale slope he can make out the point where Green River emerges from the mountainous country to the north by the deep reentrant in the line of the Book Cliffs. By close examination he may be able to see a butte on the west side of the river, which is marked by a series of pinnacles and which is known as Gunnison Butte, in commemoration of the survey of this region by Capt. Gunnison. (See Pl. LXXXII, *C*.) This butte towers 2,700 feet above the river, but as seen from the train it seems to be

not more than 300 or 400 feet high. Very few published reports regarding the early exploration of this part of the country are available. Gannett [65] refers to the early history as follows:

> From a very early time this region was traversed by Spanish caravans, traveling from Santa Fe, N. Mex., to Los Angeles, Calif. The old Spanish trail, which these caravans followed, entered Utah on the east near Dolores River, crossed the Grand [Colorado] near the Sierra La Sal and the Green at the present crossing of the Rio Grande Western Railway. It reached the valley of Sevier River near its bend and, turning south, followed its valley to the head and down the Virgin to a point near its mouth, whence it turned westward, running out of the State near its southwest corner. This traffic, which at one time was great, left, however, no trace behind in the form of a settlement. * * *
>
> The earliest recorded exploration of any part of Utah was a journey by two Franciscan fathers, Escalante and Domínguez, from Santa Fe, N. Mex., to the shores of Great Salt Lake in 1776–77. So far as can be learned, their route followed in the main that of the old Spanish trail, and it is not at all improbable that they were the pioneers in laying out the western part of this route to southern California. So far as known, they were the first white men to visit the eastern part of the Great Basin of Utah. This journey was not, however, fruitful in geographic discovery, except in the fact that it may have determined the route of travel between the Spanish settlements of New Mexico and those of California.

Thus it seems probable that while the original colonies on the Atlantic seaboard were waging their war for independence, Fathers Escalante and Domínguez were marking out the old Spanish trail and even crossing Colorado River at or near the same point where the travelers of to-day cross it on the trains of the Denver & Rio Grande Western Railroad. The next notable journey of exploration in this part of the country, at least by English-speaking people, was that of Capt. Gunnison in 1853. He likewise crossed the river at this point, but after reaching the west bank he veered off to the south and followed the Spanish trail instead of the route now followed by the railroad.

In its descent from the east the railroad runs into a shallow valley, which conceals the view of the surrounding country, and finally comes out on the east bank of Green River at a little village called Elgin. The change from the barren slopes of shale to the beautiful green of the cottonwood trees and the brilliant fields of alfalfa is very grateful to the traveler, and he welcomes the sight of running water. It is true that Green River is generally muddy, but even if it is he looks upon it with pleasure and almost with reverence, because a stream of this size that can persist through so many miles of semiarid land excites curiosity and admiration. The river is spanned by a fine steel bridge (see Pl. LXXXIII), and a mile farther west is

[65] Gannett, Henry, A gazetteer of Utah: U. S. Geol. Survey Bull. 166, pp. 10–11, 1900.

the station of Greenriver, an oasis in this inhospitable desert, at the lowest point on the Denver & Rio Grande Western Railroad. In this region the summer temperature is almost torrid and the precipitation is slight, probably about 6 or 7 inches annually. Water has here been taken from Green River for the irrigation of a small area that has been made to produce almost all kinds of crops and fruit. Fruit trees flourish here, as shown in Plate LXXXIV. A much larger area could be irrigated, though at much greater expense, by damming Green River in the canyon far above the town and constructing expensive canals to carry the water high up on the surrounding slopes. Sooner or later this work will be done, and then Green River valley will rival Grand Junction in the acreage under cultivation and in the abundance of its products.

Greenriver.

Elevation 4,080 feet.
Population 771.
Denver 555 miles.

Where it is crossed by the Denver & Rio Grande Western Railroad Green River is a quiet, peaceful stream, as shown in Plate LXXXIII, flowing in a broad valley with low banks. It is hard to realize, therefore, that above this place it is a roaring torrent, confined in narrow walls hundreds if not thousands of feet high, and that 50 miles downstream it joins the Colorado, which there enters the grandest canyon in the world.[66]

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[66] It is impossible here, in describing Green River, to avoid mentioning the exploration of this wonderful stream and its southward continuation, the Colorado, in 1869 by Maj. John W. Powell, who afterward became the Director of the United States Geological Survey. Although Maj. Powell had lost his right arm on the battle field of Shiloh, this loss did not deter him from attempting the descent of the canyon of the Colorado, an exploit that few men physically perfect have been able to accomplish.

For a number of years prior to 1869 Powell had been doing geologic and geographic work in the Uinta Mountains and the adjacent plateaus, and he had many times looked down into the swirling waters in the bottoms of the unexplored canyons and longed to embark upon them and learn the secret of the canyon land. He thus fell under the spell of the Grand Canyon, and for many years he dreamed of exploring it, although up to that time no one who had been brave or foolhardy enough to attempt to ride the current of the mighty Colorado had lived to tell the tale. Powell was warned by the Indians that no one who entered the secret and sacred precincts of the gods, as the Indians conceived the canyon to be, could expect to come out alive. But such tales only whetted his curiosity and spurred him on to increased activity. In his narrative (Exploration of the Colorado River of the West and its tributaries, p. 7, Washington, 1875) Powell says:

"The Indians, too, have woven the mysteries of the canyon into the myths of their religion. Long ago there was a great and wise chief who mourned the death of his wife and would not be comforted until Ta-vwoats, one of the Indian gods, came to him and told him she was in a happier land and offered to take him there that he might see for himself if upon his return he would cease to mourn. The great chief promised. Then Ta-vwoats made a trail through the mountains that

GREEN RIVER.

Here the river is quiet and sluggish, seemingly gathering its strength for the wild plunge through the great canyons that lie below. Photograph furnished by the Denver & Rio Grande Western Railroad.

APPLE TREES IN BLOOM.

Green River is the center of a considerable fruit-growing district. When in full bloom the orchards present an exceedingly beautiful aspect, excelled only by their appearance when the fruit is full grown. Photograph furnished by the Denver & Rio Grande Western Railroad.

A few hundred feet west of the station at Greenriver the railroad has cut through the dark shale at the base of the Mancos formation. If the traveler could have the opportunity of leaving the railroad coach and of walking through this small cut he would find that almost every fragment of shale is covered with impressions of shells. Experts who have studied these shells say that at one time each was inhabited by an animal that lived in the sea and that when the animal died the shell was filled with the dark mud that has since been consolidated into shale. The form and all the delicate markings of these shells have been well preserved. The general distribution of this shale in New Mexico, northeastern Arizona, eastern Utah, Colorado, Wyoming, Montana, North Dakota, and South Dakota shows that the sea in which it was deposited must have been of great extent and that the Rocky Mountains of to-day could not then have been in existence. Geologic evidence over all the world shows that its surface has been continually changing. At one time a region may be covered with water; at another time it may have been a plain much like that which the traveler crossed east of Denver; and at still another time it may have been high land, with mountains. Such a succession of changes has been repeated many times, with infinite variations, through all the ages, and the present age is no exception but is also a scene of general change or transformation. Such a transformation is going on to-day as in the past, but we are scarcely aware of it, for it is so

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intervene between that beautiful land, the balmy region in the great west, and this, the desert home of the poor Nu-ma.

"This trail was the canyon gorge of the Colorado. Through it he led him, and when they had returned the deity exacted from the chief a promise that he would tell no one of the joys of that land lest, through discontent with the circumstances of this world, they should desire to go to heaven. Then he rolled a river into the gorge, a mad, raging stream that should engulf anyone that might attempt to enter thereby.

"More than once have I been warned by the Indians not to enter this canyon. They considered it disobedience to the gods and contempt for their authority and believed that it would surely bring upon me their wrath."

One of the Indians described to Powell the fate of some members of his tribe who attempted to run one of the canyons of Green River in the following graphic manner:

"'The rocks,' he said, holding his hands above his head, his arms vertical, and looking between them to the heavens, 'the rocks h-e-a-p, h-e-a-p high; the water go h-oo-woogh, h-oo-wough; water pony [boat] h-e-a-p buck; water catch 'em; no see 'em Injun any more! no see 'em squaw any more! no see 'em papoose any more!'"

Despite these admonitions Powell made preparations to undertake the descent of the canyons, and on May 24, 1869, he floated away from the frontier settlement of Green River, Wyo, with a party of ten men in four boats. One of the boats was wrecked in the canyon of Lodore, where the river cuts through the great mass of the Uinta Mountains, but none of the party was lost. The expedition passed what was then called Gunnison's Crossing, now

slow that even during the entire period of human history it has made but little progress.

After the train surmounts the slight rise out of the valley of Green River the traveler will see spread wide before him one of the most desolate landscapes that he has thus far passed in his western trip. For miles the surface of the plain consists of bare clay or shale without so much as a clump of sagebrush or greasewood to break its monotony. The soil is the same as that about Green River and at Grand Junction and Montrose, in Colorado, and all that it needs to transform it from a scene of desolation to one of peace and plenty is water. To-day it is desolate and waterless, far from the homes of men, inhabited only by beasts and birds of prey. Even these are not always seen, and the traveler who is unfamiliar with the country may imagine that it is totally without animal life; but should he camp here in the desert for a time he would find that at morning and evening it is alive with birds and animals eagerly seeking food and ready to fight for it.

West of the crossing of Green River, at what is now the town of Greenriver, the old Spanish trail divided. The main trail, which

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Greenriver, Utah, on July 13, and thence went into the Grand Canyon of the Colorado. Here they met many mishaps but found no falls over which they could not take their boats, and in time they reached the deepest part of the canyon; but they had lost their instruments and had no means of estimating the distance yet to be traveled to the Mormon settlements at the mouth of the Grand Wash. Their progress was slow, too, and provisions began to run short, and several of the party became discouraged and dissatisfied. Powell did all he could to induce the men to remain with the expedition, but three of them decided to abandon the river and attempt to climb out of the canyon. These men succeeded in reaching the plateau only to be killed by the Indians, who did not believe their story about coming down through the canyon but thought they were white men from across the river who had killed a squaw in a drunken brawl. What made their fate more tragic was the success of Powell and his remaining men, who continued down the river and on the next day reached the mouth of the canyon, and on the day following arrived safely at the mouth of Virgin River.

No romance is more entertaining and exciting than the account of this expedition, told in the plain, simple language of Maj. Powell, or than the account by Dellenbaugh of Powell's second trip, made in 1871 and 1872, to verify and extend the fragmental scientific observations recorded during some parts of his first trip. To-day a fitting monument to Maj. Powell stands on the brink of that titan of chasms at Grand Canyon to commemorate his exploration.

The pioneer trips thus made by Maj. Powell in hardship and peril prepared the way for the topographic engineers and geologists of the Geological Survey, who to-day, more than 50 years later, guide their motor boats with confidence, though even yet not without danger, over stretches of the river traversed by the Powell party. These engineers are doing pioneer work of another sort, for they are making plans by which the river can be used for irrigation and for generating power, so that men can make homes in this still wild country.

led to southern California, turned to the south and crossed the Wasatch Plateau at Emery Canyon; the other branch of the trail turned to the north and followed practically the present line of the Denver & Rio Grande Western Railroad. By crossing southern Utah over the old Spanish trail the early travelers gained a general knowledge of that country. It was soon settled by bands of Mormons sent out by Brigham Young, and its settlement led to the location of the first capital of the Territory of Utah in its southern part.[67]

The train pursues a westerly course through the barren wilderness of clay flats, low shale hills, and dry beds of the desert watercourses. Water is so scarce in this region that at each siding the railroad company has built cisterns to which it hauls water in tank cars for long distances. The rainstorms here are generally violent; the water falls in torrents, the desert becomes a sea of mud, and the rushing streams cut deep channels and dissolve their banks as if they were made of sugar. At times even the railroad trains have been engulfed by streams which during more than eleven months of the year carry not a drop of water.

The great south face of Beckwith Plateau, a point that runs off southward from the main mass of the Book Cliffs, looms up prominently on the north (right), as shown in Plate LXXXV, but in the other direction there is no prominent feature to attract attention; one can look southwestward across the adobe plain as far as the eye can see and distinguish nothing but the dim outline of the Henry Mountains, far away in the hazy distance.

Six miles west of Greenriver, at milepost 561, the railroad curves to the north and follows the shale valley on the west side of the Beckwith Plateau. As the train goes around the curve the traveler may get on the left an excellent view of the east side of the San Rafael Swell, a great uplift of the rocks that involves all the geologic formations he has seen on his journey and even the underlying granite in a large area in the middle of the uplift. The sedimentary rocks on the east side of this elongated dome have been sharply upturned, and the heavy beds of sandstone between the notches cut by the streams

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[67] It was originally planned to locate the capital of Utah at Salt Lake City, but when the Territory was created in 1850 it was decided that the capital should be more nearly in the center of the Territory. The County of Millard was therefore created, and on October 29, 1851, the city of Fillmore was laid out as the capital, both the city and the county being named for Millard Fillmore, then President of the United States. A State house was begun but never finished. The legislature held but one full session at Fillmore—that of 1855–56. Several succeeding legislatures met there in order to comply with the law but did no business except to adjourn to Salt Lake City, which was finally made the capital.

have been left standing as great tables tilted to the east at an angle of 30° or 40°, which as seen from the train resemble the teeth of a gigantic saw. This line of tilted sandstone can be followed by the eye for many miles, but in the distance it fades into the misty blue of the desert. The beds nearer the traveler are upturned less steeply and have not been removed by erosion, so they form a great swell, but even where the rocks lie nearly flat the streams have cut into them deep canyons, having nearly or quite vertical sides, which measure hundreds or perhaps a thousand feet in height. The profiles are all angular; they are composed of straight lines; and when viewed from a distance these immense pinnacles of rock resemble the ruins of some ancient city, and in imagination one can see in them the remains of temples, pyramids, columns, and arches standing in grandeur amid the wreck of the structures of which they once formed a part. Here one can not resist the temptation to let the imagination have free rein—to rebuild these ruins as wonderful habitations of ancient giants and to picture the dramas that may have been enacted in them. If the traveler is fortunate enough to see these ruins when the sun is just setting behind their massive piles and suffusing their domes and pinnacles with great golden halos he can readily understand how a savage race might have here received the inspiration to build a magnificent temple to the sun, which to our minds might rival the most wonderful temples of the Egyptian kings.

At the point where the railroad makes the turn around the Beckwith Plateau it is at a considerable distance from the front of the plateau, but farther north it approaches the front more and more closely, until near the siding called Desert it is so close that the traveler may see, if the light is just right, all the delicate lines of erosion that the rain has cut in the shale slope.

The great anticline called the San Rafael Swell extends far to the north, and the rocks of the Book Cliffs bear the same relation to those in the anticline as the rocks of the Book Cliffs at Grand Junction bear to those of the Uncompahgre Plateau. The Book Cliffs west of Green River look different from those with which the traveler is familiar east of it. East of Green River the rocks weather into many projecting points or salients of hard rock, and between these points there are deep notches or reentrant angles. In addition, the upper beds of sandstone have weathered back much farther than the lower beds, but each layer is characterized by the same kind of salients and reentrant angles. The result of this form of weathering is a front that is extremely irregular and jagged. West of Green River the front of the Book Cliffs is very regular; it shows no tendency to weather into long points. This difference is probably due

to the absence of streams and to the presence of a greater number of beds of sandstone in the west than in the east, as well as to the more massive character of these beds and to the greater dips which prevail in this part of the plateau, for all these characteristics would give a very different result in the forms produced by erosion. The Book Cliffs west of Green River are characterized by many bands of sandstone, which may be followed by the eye for long distances and which produce slight benches on the slope. A profile of a part of the front of the Beckwith Plateau is shown in figure 55.

A geologist accustomed to interpret the meaning of land forms sees almost everywhere in these shale areas fragments of older surfaces of the land, preserved in terraces and benches. Some of these remnants of an older surface were pointed out west of Grand Junction and again near Thompson. West of Green River they grow more and more prominent as the traveler approaches the head of the stream. They stand at different heights above the present general surface, but commonly some particular terrace—one that ranges in height from 50 to 200 feet above the present surface—is more prominent than the rest. The old surface in this region was probably more nearly smooth and regular than the surface of to-day, and its slope was doubtless not so great as that of the present surface. After this old surface had been well developed, the lower country, though it showed considerable differences in elevation between the higher and the lower parts of its slopes, must have formed one general plain. Then came a change, either an uplift of the land or an increase in the rainfall. At any rate, the streams were able to cut deep trenches in this old surface, and their work has been continued so long that it has left, here and there, only remnants of the once continuous surface, and these remnants are the terraces and benches that we see to-day. Terraces are very prominent in places west of Woodside, and the traveler may be interested in studying them, not as terraces but as remnants of that old surface. Indeed, he may be able in imagination to reconstruct from them the old surface as it existed before the streams had cut into it and carved the valleys of to-day.

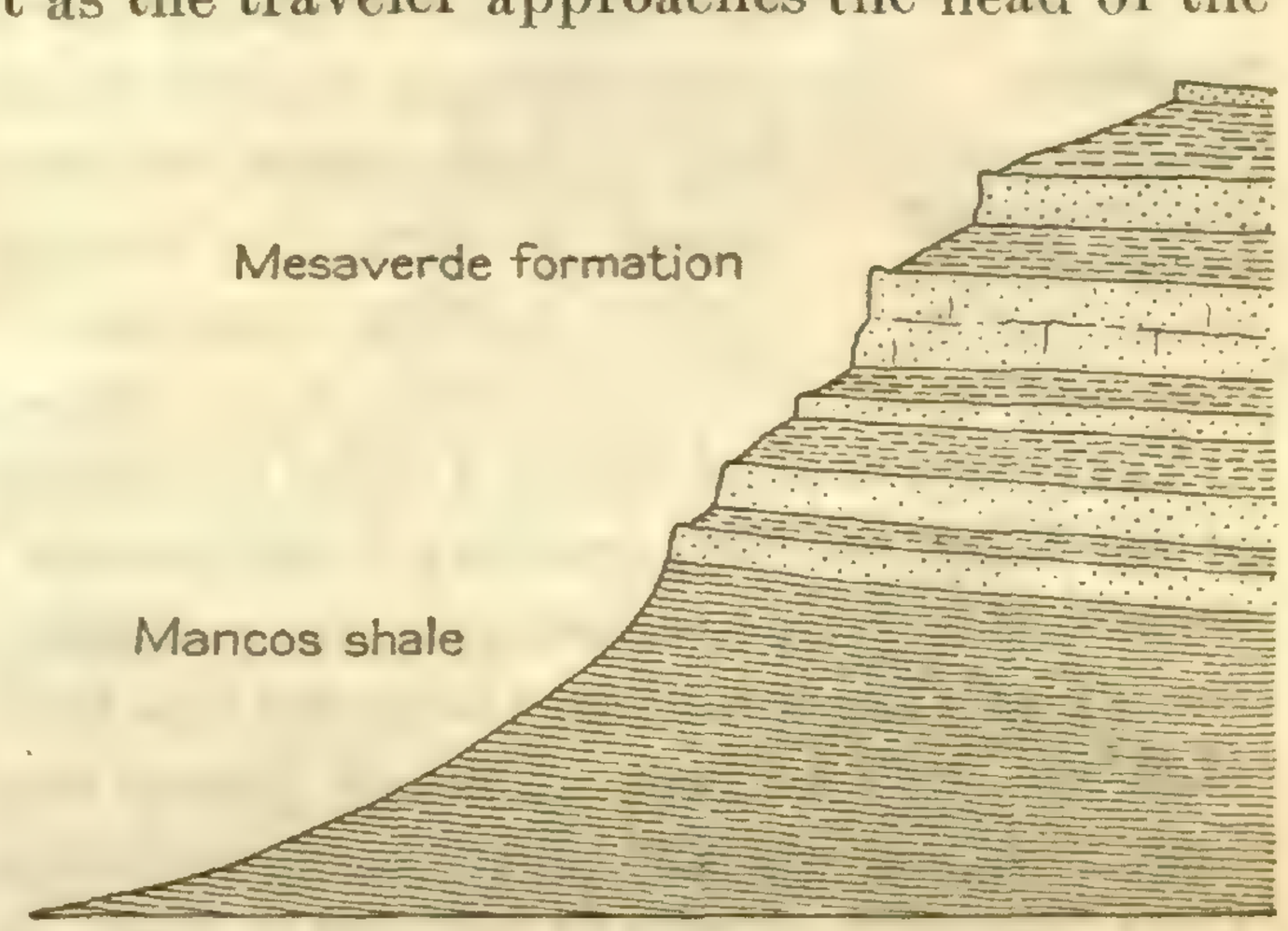

FIGURE 55.—Profile of front of Beckwith Plateau.

The railroad rises steadily until it reaches a local summit at Cliff siding, between mileposts 574 and 575, and then begins a rapid descent to Price River, the master stream in the north end of Castle Valley. This stream heads on the Wasatch Plateau, far to the northwest, and flows across the north end of the San Rafael Swell, beyond which it joins Green River through a deep canyon cut in the Book Cliffs just north of the Beckwith Plateau. The traveler may see the entrance to this canyon by looking ahead on the east (right) after passing Cliff siding.

Cliff.

Elevation 4,819 feet.
Denver 575 miles.

The line of cottonwood trees that marks the course of Price River may be seen long before the train has reached the bottom of the valley, and their soft green color is very refreshing to the eye that has been gazing on the barren expanse of desert just crossed. At Woodside the railroad crosses Price River, which the traveler unaccustomed to this region may not be willing to call a river unless he remembers that most of the water it normally carries is withdrawn for irrigation farther upstream, and then he may wonder that any water at all is left in it at Woodside.

Woodside.

Elevation 4,645 feet.
Population 124.*
Denver 581 miles.

For a distance of about 3 miles the railroad follows the east bank of the river through groves of cottonwood trees and small irrigated farms. Its course here lies near the west margin of the belt of shale, and the underlying sandstone (Dakota) and the red and green rocks of the McElmo may be seen at many places across the river on the left. Near milepost 583 the river ceases to follow the shale and swings in from the west, where it has cut a deep and narrow canyon in the hard rocks across the north end of the San Rafael Swell. The railroad engineers sought to avoid this canyon by following the broad valley that Grassy Creek has cut in the shale. This valley is the extension of the one that the train has followed ever since it left Green River.

The valley was not formed by a downfold in the rocks but simply by the erosion of the soft Mancos shale. The traveler may understand this easily by looking at the higher rocks in the face of the Book Cliffs on the east and the lower rocks in the San Rafael Swell on the west and noticing that they dip in the same direction—toward the northeast. From time to time as the traveler may be able to look ahead he can see that apparently the valley is filled and cut off by terraces that rise 100 feet or more above the level of the track, as shown in figure 56. These terraces appear to bar the further passage of the railroad, so it turns to the left a short distance beyond Grassy siding and climbs out of the shale valley. In making this climb the road turns and twists about some of the barren shale hills,

GEOLOGIC AND TOPOGRAPHIC MAP

OF THE

RIO GRANDE ROUTE

From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
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1922

EXPLANATION

		Age	Thickness in feet
E	White shale and sandstone (Green River formation)	Tertiary (*Eocene*)	2,600
F	Red sandstone and conglomerate (Wasatch formation)	Tertiary (*Eocene*)	3,000
H	Sandstone, shale, and coal beds (Mesaverde formation)	Upper Cretaceous	2,200
J	Dark marine shale (Mancos shale); in lower part sandstone (Ferron sandstone member, Fer)	Upper Cretaceous	3,000
M	Brown sandstone (Dakota sandstone)	Upper Cretaceous	50
N	Variegated shale and sandstone (McElmo formation and La Plata sandstone)	Cretaceous (?) and Jurassic	1,800

Fault

BECKWITH PLATEAU.

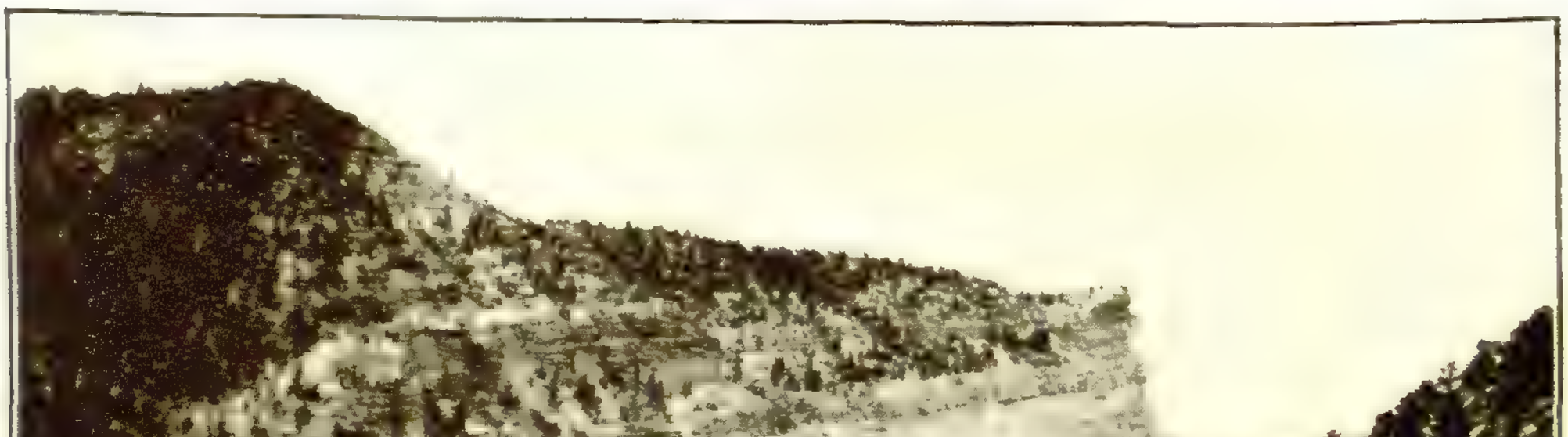
Beckwith Plateau is one of the landmarks west of Green River. The coal-bearing sandstone on the top is broken into fantastic forms, and the shale slopes below are marvelously sculptured by the rain. It stands in the midst of one of the most desolate flats that the traveler will see east of Salt Lake City. Scarcely a shrub or plant of any kind breaks the monotony of this expanse of barren clay. Photograph furnished by the Denver & Rio Grande Western Railroad.

A. BAND OF SHEEP.

One of the important industries in this part of Utah is sheep raising. The bands of sheep, each band under the guidance of a herder or two, range from the low grounds of the desert in the winter and early spring to the highest ridges and plateaus in midsummer. Photograph by Frank R. Clark.

B. COKE OVENS AT SUNNYSIDE.

The Sunnyside mine of the Utah Fuel Co. is not on the main line of the railroad, but it is served by a branch which connects at Mounds. The coal mined at Sunnyside is the only coal in the State that will make commercial coke. Photograph by Frank R. Clark.



C. CLIFFS ABOVE HELPER.

The cliffs of sandstone underlain by shale are striking features as the traveler looks up at them from Helper, but when seen from the top they are equally interesting, for one can follow, with the eye, the various beds and note the form of sculpture of each particular layer. Photograph by Frank R. Clarke.

cuts through others, and finally, at Cedar siding, approaches the margin of the shale and at the same time attains the level of the great terraces that were so conspicuous from points near Grassy siding. When seen from their own level these terraces are very extensive and appear like a vast flat plain.

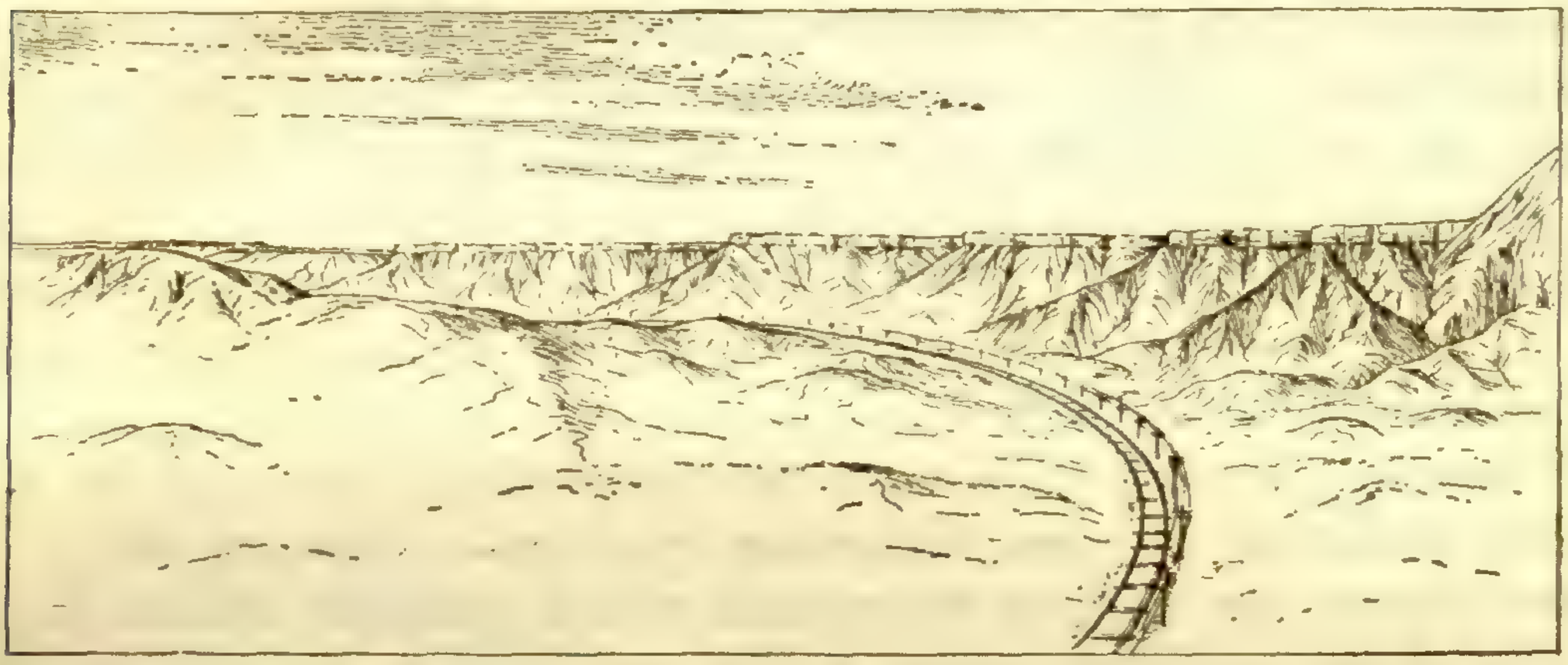


FIGURE 56.—Terraces at head of Grassy Creek valley.

Cedar.

Elevation 5,166 feet.
Denver 594 miles.

In the vicinity of Cedar siding the lower part of the shale contains many beds of sandstone and some conglomerate. This part of the formation thickens considerably toward the south for 20 or 30 miles to a place where it contains several valuable beds of coal and is known as the Ferron sandstone. About a mile west of Cedar siding a sharp upward bend of the rocks terminates the outcrop of the shale and brings to the surface the Dakota sandstone and, underlying it, the maroon and green beds of the McElmo. The railroad at this point is on the bank of a creek called Sunnyside Wash, and it follows the valley of this stream to the north until near milepost 600 the railroad passes from the varicolored beds of the McElmo into a broad, flat valley cut in the Mancos shale.

On the right may be seen the branch line of the Denver & Rio Grande Western that leads to Sunnyside, one of the largest coal mines in the district and the only one that produces a merchantable quality of coke.[68] Plate LXXXVI, *B*, shows the coke ovens at Sunnyside. The two lines run nearly parallel for some distance but finally unite at the station of Mounds. (See sheet 9, p. 232.) To the casual traveler the country over which he has been riding, as well as that which he can see about Mounds, probably appears to be barren and valueless, but should he pass this way in sheep-shearing time

Mounds.

Elevation 5,442 feet.
Denver 603 miles.

[68] The following description of the mines at Sunnyside is given by Frank R. Clark, who has made a careful geologic survey of the region:

Coal has been mined at Sunnyside since about 1900. The town, mine tipple, and coke ovens are in the mouth of Whitmore Canyon at the end of the

and have a few hours to examine the shearing plant which stands just north of the station, he might change his mind, for this is the center of a large sheep industry. It is said that 100,000 sheep were sheared at this plant during the season of 1916 and that many sheep were turned away.

It must be remembered, however, that the sheep sheared here do not depend upon this immediate vicinity for their pasture, for the sheep herder wanders with his flock during the summer into the high country of the San Rafael Swell (see Pl. LXXXVI, *A*) and in the winter seeks the protection of the lower valleys. The sheep would soon starve on a small area, but there is much open range—that is, unfenced Government land—in this country and by constant migration the sheep do well.

From the vicinity of Mounds the traveler may see that the Book Cliffs, which he has been following, continue northward only a few miles beyond the mine at Sunnyside, which generally can be located by its smoke, and there swing to the northwest to the head of Price River, near Helper, and there again change their course to a direction a little west of south—that is, they encircle the north end of the San Rafael Swell. The name Book Cliffs, however, is applied only to the part that lies east and north of the Denver & Rio Grande Western Railroad; the part that lies south of the railroad is known as the edge of the Wasatch Plateau. All these features can readily be seen from the train in the vicinity of Mounds.

Sunnyside branch, about 18 miles east of Mounds. Two beds of bituminous coking coal, separated by 5 to 25 feet of sandstone and shale, are mined here. The lower and thicker coal bed ranges in thickness from 5 to 14 feet and the upper bed from 3 to 6 feet.

Mine development has been rapid and continuous since the beginning, and now the workings cover several square miles. An electric plant furnishes power for hoists and hauling motors, and light for town and mines. Power is also carried by a high-voltage line eastward over the mountain into Range Creek, a distance of 5 miles, where it drives pumps which deliver all the water used at Sunnyside for domestic purposes and for steam boilers. The daily output of the mines is about 2,500 tons of coal, most of which is converted into coke in beehive ovens. The coke and coal are hauled by "locals" from the mines to Helper, where through freight trains are made up. Most of the coke from Sunnyside is shipped to the smelter at Anaconda, Mont.

The coal at Sunnyside and throughout the Book Cliffs has been generally burned at the outcrop, producing a reddish color in the associated rocks. The burning has advanced inward along the coal bed at many points for more than 1,000 feet and beneath 1,000 feet of overlying material. The mine workings at Sunnyside have in several places surrounded the burned-out areas, thus showing the extent of the burning. The fire has penetrated the coal farther on the points of ridges between drainage channels than it did where the coal outcrop crosses the stream courses.

Just west of Mounds curious hard masses of rock which on account of their nearly spherical shape are frequently referred to as "cannon balls" may be seen in the shale that forms the cut edge of one of the terraces. These round masses of rock are known to geologists as concretions,[69] and they were undoubtedly formed in the shale after it was deposited as mud in the bottom of the ocean.

From the uplands at Mounds the road descends westward to Price River, which it reaches at milepost 607. Here the traveler is once more gladdened by the sight of green trees and small irrigated farms in the river bottom. The valley becomes rather narrow, and at Farnham the bluffs of shale encroach closely upon the river bottom. The shale hills are gray and barren, but they form a background that serves to heighten the color of the fields and trees.

Farnham.

Elevation 5,313 feet.
Denver 609 miles.

From Farnham the railroad follows Price River practically to its head. Irrigation is generally practiced in the valley, but the supply of water is not sufficient to serve all the land that is otherwise favorably situated. Towns have sprung up along the railroad and are achieving more or less success. The next town to be passed is Wellington, which appears to be a thriving village, whose most prominent building is a modern schoolhouse.

Wellington.

Elevation 5,415 feet.
Population 534.
Denver 614 miles.

Northwest of Wellington the valley is more open, and well-irrigated farms are abundant. The country on both sides of the river is served by canals that take their water from the river several miles above Price. Price is the county seat of Carbon County, which was so named because of the great beds of coal that are found in the Book Cliffs. It is a general supply point for the ranches in Duchesne Valley, north of the Book Cliffs, and in Castle Valley, south of them.

Price.

Elevation 5,546 feet.
Population 2,364.
Denver 619 miles.

For a distance of 4 miles above Price the course of the river is southeastward and its bottom lands are fairly wide. The railroad is in this bottom and affords good views on both sides of the best part of the irrigated district. From this open valley the traveler may see the shale terraces extending toward the river from both sides, like long fingers, and at milepost 623 they approach so closely that the river flows in a veritable shale canyon, with steep walls on either hand that rise to a height of nearly 100 feet.

[69] The origin of concretions is not well understood, but they are supposed to be due to the collecting together in the mud of certain mineral particles, in much the same manner as the molecules of a mineral unite to form a crystal. Concretions, however, are generally rounded, or at least they are without sharp corners or straight sides, though they may take on a variety of forms, some of which are very complex and fantastic.

At this point the river also changes its course, coming out of the Book Cliffs in a course nearly due south. The valley continues narrow, with shale bluffs and a narrow strip of irrigated bottom land. Just beyond milepost 625 a branch line on the east (right) leads to Kenilworth, a mining town that produces a notable part of the coal shipped from this region. About a mile farther north, in a valley so narrow as scarcely to provide room for a single street, is the railroad town of Helper, which was so named because here are kept the light engines that serve the regular trains as "helpers" up the heavy grade north of the town. The town is at the mouth of the canyon that Price River has cut in the plateau of which the Book Cliffs are the front. These cliffs loom up 1,500 feet above the station and seem to interpose a blank wall against the further progress of the railroad, but like many other things in this world their appearance is deceptive, for the railroad has succeeded in following the stream through the narrow cleft. A view of the cliffs from above is shown in Plate LXXXVI, *C*.

Helper.

Elevation 5,840 feet.
Population 1,606.
Denver 627 miles.

The canyon above Helper shows at close range the character of the coal-bearing (Mesaverde) formation. The lower part of the cliff overlooking Helper is composed mainly of shale (Mancos), which originated in the sea and therefore contains no coal. The rocks above this shale are mainly sandstones, but there are also many beds of shale, and in places there are coal beds, which range in thickness from a few inches to as much as 20 feet. An old prospect in one of the thick beds is shown in Plate LXXX, *B* (p. 195). The coal beds, however thick they may be, can not generally be seen from the car windows, for they are the softest members of the formation and consequently weather back faster than either the shale or the sandstone, so that their outcrop becomes covered with soil and broken rock. Sandstone makes up the greater part of the formation, and its general color is light gray or nearly white. It has been described as red, but this is a mistake, as the formation contains no red sandstone, though a ledge on weathering becomes a rusty brown, or if a coal bed below it has been burned it may have become a bright red, but these are not the inherent colors of the sandstone.[70]

[70] The following description of the coal beds and the associated rocks in the vicinity of Castlegate is given by Frank R. Clark:

At the mouth of Price River canyon nearly vertical cliffs of sandstone and shale rise 1,500 feet above the river bed. These cliffs are capped by beds of sandstone that form the lower part of the Mesaverde formation. The beds that compose the cliffs were laid down in fresh water or on the land. They rest upon soft dark shale (Mancos), which was laid down in a shallow sea that covered most of the country. The line between these formations is generally drawn at the base of the heavy ledge-making sand-

Half a mile above Helper a branch railroad turns back to the left up Spring Canyon to coal mines at Storrs, Standardville, and other towns where mines have recently been opened, and about 2 miles above Helper the Utah Railway, a new line built to replace the one from Price to Hiawatha, connects the mines at Hiawatha, Mohrland, and Wattis with the Denver & Rio Grande Western.

The scenery in Spring Canyon, as in many others on the road, is dominated by great sandstones. This dominance is shown particularly by the narrowness of the canyon. Where the base of the cliffs is composed of shale the canyon is wider, as can be seen in the first 2 miles above Helper, but where the canyon walls are composed largely of sandstone, as they are farther up, the canyon is narrow, barely affording room for the automobile highway, the railroad, and the river. The walls of the canyon also show the effect of the different rocks; where they are mainly shale they have a pronounced slope, but where they are mainly sandstone they are precipitous and in places vertical. Each spur that projects into the canyon is preserved by heavy sandstone, and therefore the characteristic feature of the canyon is the many sandstone points which stand up like walls or dikes.

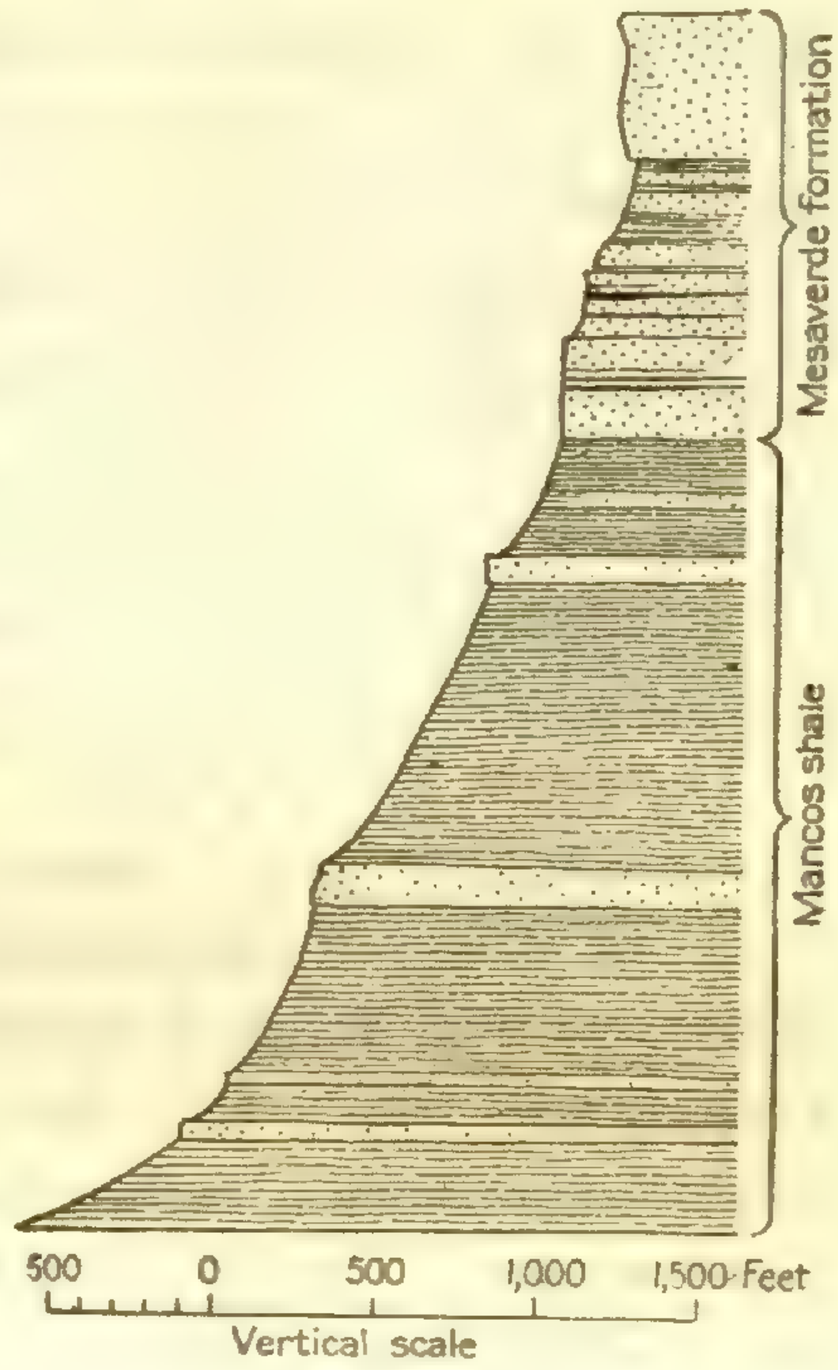


FIGURE 57.—Geologic section at Castlegate.

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stone or at the top of the main mass of marine shale. The upper part of the Mancos shale in Price River canyon contains several prominent beds of sandstone (see fig. 57), which wedge out toward the east. The lowest of these beds crosses Price River about 3 miles below (south of) Helper, and the upper one crosses the river about midway between the town of Panther and the tipple of the Panther Coal Co.

The Mesaverde contains several coal beds which differ in thickness from place to place but where thickest are of great value. Coal is mined on a large scale along Price River canyon and its tributaries at Kenilworth, 2½ miles east of Helper; Panther, half a mile south of Castlegate; Castlegate; Cameron, 1½ miles northwest of Castlegate; Storrs, 3½ miles northwest of Helper; Standardville, 4½ miles northwest of Helper; and Hiawatha, 13 miles southwest of Price. The coal at Castlegate was formerly coked, but as the Sunnyside coal proved to be better adapted to coking, the Castlegate coking plant was abandoned. Three coal beds are mined at Kenilworth. The upper and lower ones are 18 to 20 feet thick, and the middle one is 4 to 6 feet thick.

The Castlegate group includes four coal beds, which differ greatly in thickness from place to place but are locally minable. At Cameron the coal does not come to the surface but is reached by a slope. The two beds that are

As the coal beds occur well up in the Mesaverde formation, they lie near the tops of the ridges at the mouth of the canyon, and the coal mines here must lower the coal by long inclined tramways to the tipple,[71] which is at railroad level. This form of handling the coal is well illustrated at the Panther mine, near milepost 629. Farther up the canyon the coal beds lie nearer the creek level, and they finally pass below water level and are seen no more.

Castlegate.

Elevation 6,120 feet.
Population 1,120.
Denver 630 miles.

The most prominent mine and mining town on the main line is Castlegate, at the mouth of Willow Creek, which enters the main stream from the east (right). The mines are on both sides of the valley a few rods above the mouth of Willow Creek, and the coal taken from them comes to a common tipple, which spans the railroad at this place.

The name "Castlegate" was taken from that of the peculiar gate-like passage 2 miles above the town, the sides of which seem to be walls or dikes of sandstone projecting from the sides of the canyon. When viewed from a point directly opposite it the rock wall on the right looks like a thin finger, as shown in Plate LXXXVII, *C*, but when seen from a point farther up the canyon the walls on the two sides seem to project so far into the canyon as almost to obstruct it and to bar the railroad from further progress. This aspect of the gateway is shown in Plate LXXXVIII. As a matter of fact the two walls are not directly opposite, though this fact is not indicated in the illustration, but are offset a considerable distance, so that the opening is not so narrow as it appears. It is, however, a striking feature of the canyon and well deserves the name "Castlegate." The spurs that form the gate are not the only projecting ledges of sandstone, for each point or spur, whether it is at railroad level or high on the mountain side, is bounded by great cliffs of gray sandstone hundreds of feet high.

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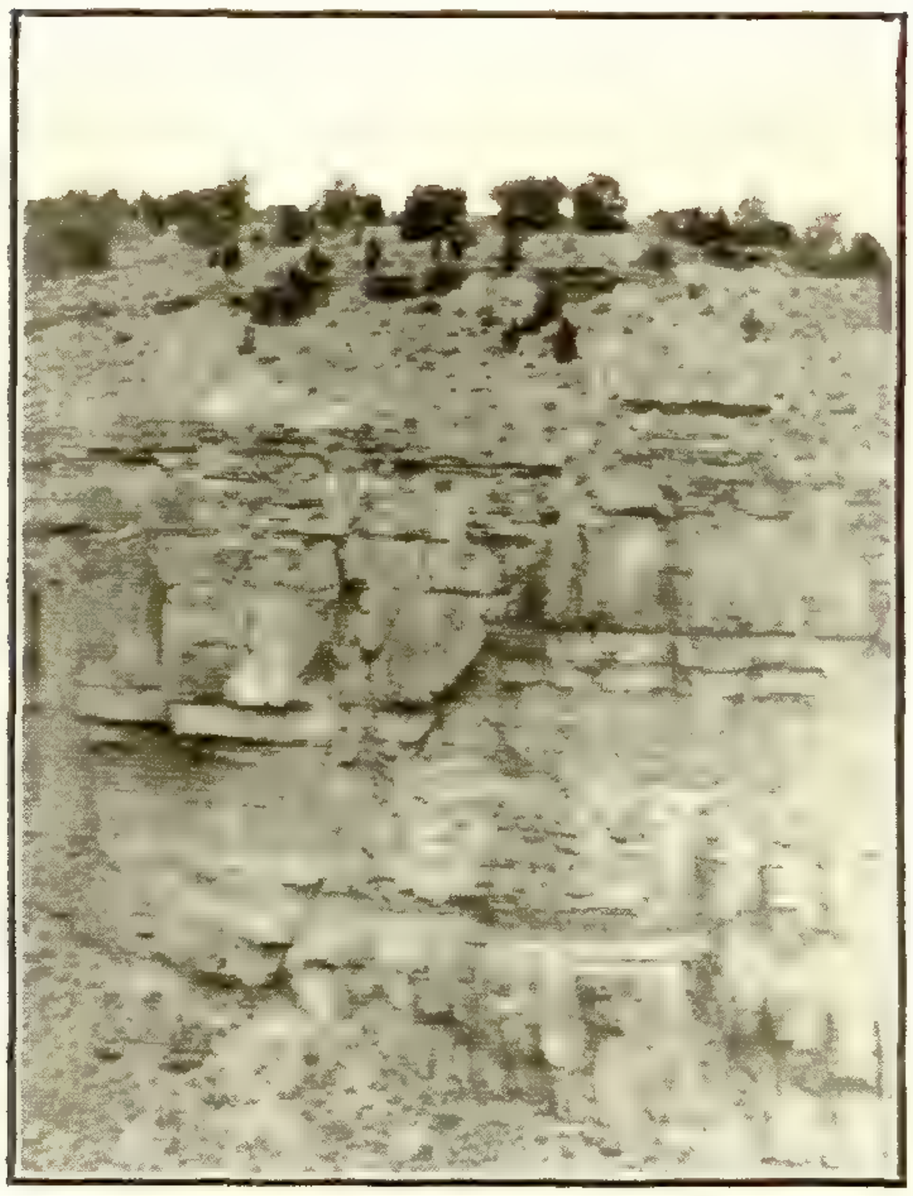
mined are probably part of the Castlegate group. On the north side of the river, at Cameron, a massive sandstone crops out in a vertical cliff about 450 feet high. This sandstone is locally known as the Castlegate "reef" and crops out for many miles from east to west. (See Pls. LXXXVII, *C*, and LXXXVIII.) The sandstone gradually becomes thinner toward the east and at Sunnyside is only about 150 feet thick.

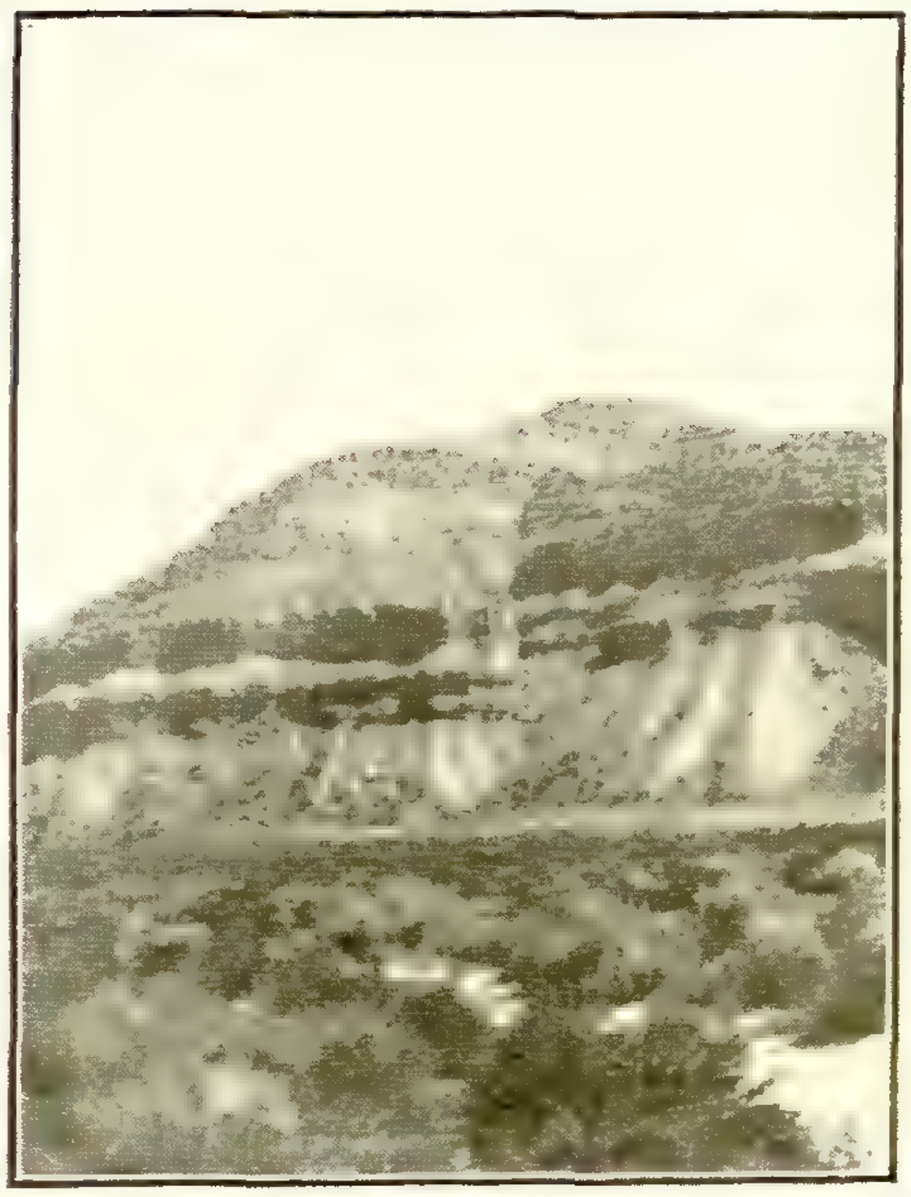
The section shown in figure 57 includes the rocks exposed from the diversion dam on Price River 3 miles south of Helper to the Castlegate "reef" sandstone at Cameron.

[71] The term "tipple" is applied in the soft-coal regions of the United States to the platform or building to which the coal is delivered from the mine. The tipple generally stands well above the railroad so that when the coal is dumped from the mine cars it descends by gravity through screens and is thus sorted into different sizes or grades before it reaches the railroad car in which it is shipped to market.



A. INCLINED NORMAL FAULT.

Displacement, 8 or 10 feet. As the surface is not offset by the fault the movement must have taken place long before the present valley was cut. Photograph by D. E. Winchester.



B. VERTICAL NORMAL FAULT.

Displacement, 60 or 80 feet. Photograph by M. A. Pishel.

C. CASTLEGATE, SIDE VIEW.

The sandstone pillar on the east (right) side of the canyon. From this point of view it appears like a slender tower of the native rock almost ready to fall from the vibration of the passing trains, but when looked at from the north after having passed through the "gate" the picture is different, as shown in Plate LXXXVIII. Photograph by Shiplers, Salt Lake City.

CASTLEGATE.

Projecting points of gray sandstone close in on the valley, leaving only a narrow passage resembling a gateway in the walls of some old ruined castle. The grade for the west-bound trains is heavy, and the canyon is generally filled with smoke. Photograph furnished by the Denver & Rio Grande Western Railroad.

Throughout the main part of the canyon the railroad climbs steadily in order to cross over the top of the Wasatch Plateau. For about 10 miles out of Helper the grade is 127 feet to the mile, and though such a grade is not excessive it necessitates the use of extra engines on some of the heavy trains to get them to the summit.

Northward the canyon gradually grows less and less rugged and the walls decrease in height until just above the first tunnel, 1¼ miles above Nolan, the thick ledges of sandstone give place to weaker beds of muddy sandstone, shale, and fresh-water limestone. Although these beds are in general gray, they belong to a different geologic formation from that which carries the coal beds at Castlegate. This formation, the Wasatch,[72] which appears just above the first tunnel, is generally red, and in many places it is very coarse, but here it is light in color and is composed of fine material. Where the less resistant rocks form the surface the slopes become smoother and less steep and the general aspect of the canyon is much subdued. These gray beds continue to a point about half a mile above the station of Kyune.

The upper part of the Wasatch is composed mostly of red clay or shale and appears to contain only a few beds of sandstone. Some of these beds have been quarried extensively above Kyune, where this part of the formation first makes its appearance. As the upper part of the Wasatch formation in this locality is composed largely of soft material, the slopes are gentle and the immediate hills are low. Here and there a harder or a thicker bed appears at the surface, and at these places the valley becomes more like a canyon.

Kyune.

Elevation 7,013 feet.
Denver 639 miles.

[72] The Wasatch formation was one of the first to be laid down in the Tertiary period. At the beginning of this period there was a wide uplift of many mountain ranges, and as soon as these ranges attained considerable height above sea level they were vigorously attacked by streams, which rolled great boulders down the steep slopes and deposited them at the foot. The finer material was carried away from the mountains by the streams, as similar material is to-day carried far away from the place where it originated, and was distributed over the fairly even surface. As water tends to drop coarse material first, the boulders, gravel, and sand were dropped near the mountains, but the clay was carried farther off, and finally all the earthy material found a resting place on the surface of the land or at the bottom of a lake. Such a lake probably existed in the Castlegate region, and in it were deposited the fresh-water limestones and shales which in this region constitute 700 or 800 feet of the lower part of the formation.

From the very manner of its origin and mode of transportation the Wasatch formation varies greatly in its composition, which depends upon the source of its material and the distance to which it has been carried. Such differences will be seen by the traveler long before he reaches the end of his journey. One feature of the Wasatch, however, is remarkably constant—its red or maroon color, which is characteristic of the formation generally throughout the Rocky Mountain region and is the most reliable means by which it can be identified.

The railroad follows the boundary between the gray and the red parts of the Wasatch formations for some distance above Kyune, cutting in places into the gray beds and in places into the red ones. A short distance west of milepost 643 the railroad leaves the red beds and for a mile it traverses the light-colored limestones and shales. In these rocks the stream has cut a canyon, which bears off to the southwest. On rounding the point of the spur that projects from the north the traveler comes into an open valley that trends northward, and on the farther (west) side of this valley lie the bright-red beds of the upper part of the Wasatch formation. These beds are brought down into view again by a northward-trending fault, which has cut the rocks for a long distance on either side of the railroad and has dropped those on the west side at least 200 feet. This fault, which passes a few hundred feet east of the station at Colton, has caused the formation of the north-south valley. From Colton a branch railroad extends southward up the valley of West Fork to the towns of Scofield, Winterquarters, and Clear Creek, where coal of about the same quality as the Castlegate coal is mined. The surface of the plateau, being composed of soft rocks, is not rugged, and it does not seem to be very high, yet several points near Colton stand nearly 10,000 feet above sea level. The plateau is a fine summer range for stock and affords pasturage for thousands of sheep.

Colton.

Elevation 7,170 feet.
Population 49.*
Denver 645 miles.

From Colton the railroad runs up a broad but short valley in the Wasatch formation to the crest of the plateau at Soldier Summit, where the main line of the Denver & Rio Grande Western Railroad reaches its highest point in the State of Utah. The summit of this pass was so named because some soldiers under Gen. Albert Sidney Johnston, who were returning from the Salt Lake Valley at the end of the "Mormon war," were buried here. A brief account of this "war," taken almost wholly from Bancroft's "History of Utah," is given in the footnote.[73] Recently the railroad company has built an extensive yard on the summit to facilitate the movement of freight.

Soldier Summit.

Elevation 7,440 feet.
Denver 652 miles.

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[73] The so-called "Mormon war" was the result of friction and misunderstanding between the Federal judges and other officers of the Territory of Utah and the Mormon people. As the Mormons had settled here before the region had passed into the hands of the United States, and as they had increased greatly in numbers, they thought they should be allowed to conduct their affairs as they saw fit. Accordingly the legislature of the new Territory proceeded to pass laws that were acceptable to the church but that were apparently obnoxious to some of the Territorial officers. As the Mormons regarded the Federal officials as "carpet baggers" there was increas-

On approaching the summit the traveler may notice on the north side of the valley, only a short distance from the track, a mine at which considerable work has been done. This mine, as well as one north of Colton and some others on the west side of Soldier Summit,

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ing ill feeling on both sides. On one occasion the records of the United States district courts were taken from a judge's office during his absence and a bonfire was made of his books and papers. He of course supposed that the records were also consumed and so made affidavit on his return to Washington. The records had, in fact, been removed and were in safekeeping; but this escapade of the mob was noised abroad with many exaggerations and excited much unfavorable comment.

After several years of friction no Gentiles could be induced to accept office in a land where, according to common belief, they could perform their duties only at the peril of their lives. Bancroft sums up the situation as follows:

"It was now established, as was supposed, on sufficient evidence, that the Mormons refused obedience to Gentile law; that Federal officials had been virtually driven from Utah, and that one at least of the Federal judges had been threatened with violence while his court was in session; and that the records of the court had been destroyed or concealed. With the advice of his cabinet, therefore, and yielding perhaps not unwillingly to the outcry of the Republican party, President Buchanan determined that Brigham Young should be superseded as governor, and that a force should be sent to the Territory, ostensibly as a posse comitatus, to sustain the authority of his successor."

In July, 1857, Albert Cumming was appointed governor and at about the same time a force of about 2,500 men was sent from Fort Leavenworth to put down the rebellion in Utah. This army was harassed by a band of Mormon forces, and when it reached Fort Bridger, Wyo., late in the autumn, found itself with supplies sufficient only to carry it through the winter and without stock to transport its equipment into Utah even if the way had been open. The commander, Brig. Gen. A. S. Johnston, decided that nothing could be done until the next summer, so he went into winter quarters near Fort Bridger.

During this unexpected delay President Buchanan was persuaded by Col. Thomas L. Kane, of Philadelphia, a Mormon sympathizer, to send him as a commissioner to Utah to investigate matters and see if a peaceable settlement could not be effected. Kane reached Salt Lake City in February, 1858, and arranged a general conference, which showed that most of the charges were without foundation. When matters reached this happy stage of adjustment the new governor was sworn in, the President's proclamation of amnesty was read throughout the Territory, and it was agreed that the army should enter Salt Lake Valley without molestation.

In accordance with this agreement, Gen. Johnston with his command entered the valley by way of Emigration Canyon on June 26, 1858, and marched to Cedar Valley, 6 or 8 miles west of Utah Lake. Here he established a camp, which he named Camp Floyd. Gen. Johnston left Utah in March, 1860, and the next year was given a command in the Confederate Army. The soldiers under his command were sent in parties to other camps as the threatening cloud of rebellion grew blacker, and it was some of these parties that followed the trail eastward over Soldier Summit and gave it its name.

were opened on veins of ozokerite,[74] but the operators have had difficulty in competing with ozokerite shipped into this country from Galicia, and the mines have never been fully developed.

As originally built the railroad on the west side of the divide followed Soldier Creek from its head to Thistle, where the creek joins Spanish Fork. This route made necessary the exceptionally steep grade of 4 per cent, or 211 feet to the mile. The operation of the road over this steep grade was very expensive, for three or four or even five locomotives were required to get a heavy train from Thistle to the summit. Recently the railroad company has abandoned this steep grade and has constructed an entirely new line which begins at Soldier Summit and extends westward for a distance of 15 miles. The new line has a grade of 2 per cent, or 106 feet to the mile, and one locomotive can haul as many cars on it as three locomotives could haul on the old line. The new line also gives the traveler a much better opportunity to see the surrounding country than the old line, which ran in the bottom of the valley.

The rocks exposed in the numerous cuts on the new line are generally red or at least are banded with red. These red rocks are the continuation of those that were seen about Colton and are undoubtedly the upper part of the Wasatch formation. The rocks dip to the north (right) at about the same angle as the slope of the mountain side, but the rocks across the ravine on the north side of the old line of the railroad are very white and carry no trace of red material. It is therefore fairly evident, as shown in figure 58, that the rocks in the cuts along the new line belong to the uppermost beds of the Wasatch, and that the white shale and sandstone across the valley are in an overlying formation which geologists have named the Green River formation, from its wide distribution in the Green River Basin, Wyo. This formation is especially prominent at the town of Green-

[74] Ozokerite, or mineral wax, is a mixture of various hydrocarbons, generally supposed to belong to the paraffin series. It varies in color from black or dark brown to light yellow, but some specimens are greenish. It may be as soft as tallow or as hard as gypsum. The lighter-colored varieties yield the largest amounts of cerasin, which is the refined product. The melting point of ozokerite is considerably above that of commercial paraffin. It occurs in fissures in the rocks and is thought to have been deposited from petroleum that formerly circulated through these fissures. The deposits are of different thickness, ranging from mere films to masses nearly 3 feet thick.

Ozokerite is used extensively for insulating electric conductors, for making candles, for adulterating beeswax, as a foundation for other waxes and polishes, to protect metal surfaces, and for making wax figures and wax dolls.

It is reported that the Utah field has produced 750,000 pounds since 1886, but this amount is insignificant when compared with the annual imports, which from 1910 to 1920 have ranged from 900,000 to more than 8,000,000 pounds.

river, on the Union Pacific Railroad, and forms the picturesque buttes back of the town.

The formations in this vicinity are the same as those that the traveler saw in Grand Valley, Colo., between Rifle and De Beque—variegated Wasatch shale at the base and white shale of the Green River formation above it. (See p. 148.)

At the siding of Scenic, 5 miles west of Soldier Summit, the traveler may look down on the north (right) and see not only the old line of the railroad 439 feet below him but also the loop over which he will pass in a few minutes. The difference between a 4 per cent and a 2 per cent grade is here brought out clearly, even to those who are not familiar with the engineering problems of railroad construction. Two miles farther on the road makes a broad

Scenic.

Elevation 6,968 feet.
Denver 657 miles.

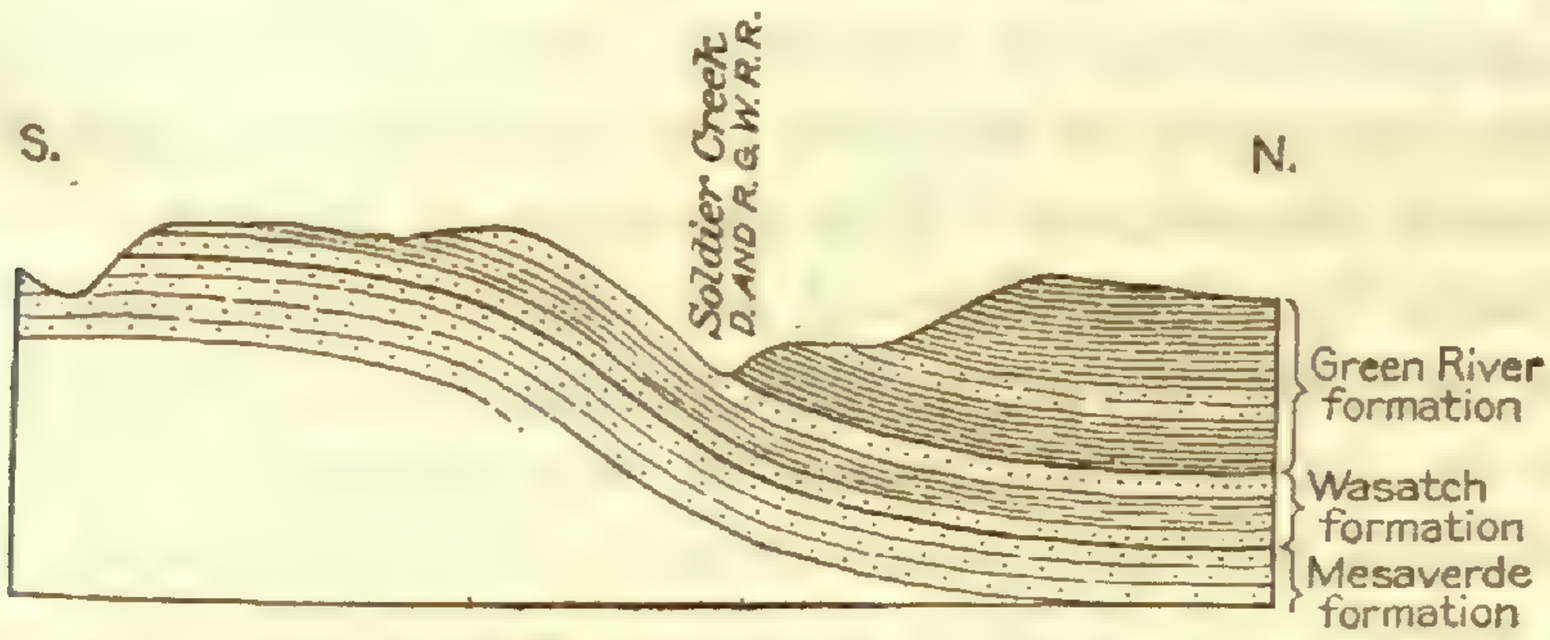

FIGURE 58.—Section at Gilluly, showing relation of the northward-dipping red Wasatch to the white Green River formation.

loop to the right, still in the Wasatch formation, and returns along the mountain side at a lower level. A reverse loop is made under the old roadbed at the station of Gilluly, and from this point down through the canyon the railroad follows the right wall, but far above the level of the old line.

Gilluly.

Elevation 6,529 feet.
Denver 661 miles.

The rocks which form the mountain side above the tracks and which have been deeply cut in order to provide a roadbed are all in the Green River formation. They are naturally dark, but on weathering they turn intensely white. Experiments have shown that oil in commercial quantity may be distilled from many beds of this shale, and it is possible that gasoline and other grades of oil, as well as fertilizer, may some day be extensively manufactured here.[75]

[75] As stated on p. 149, the Green River shale is continuous north of the railroad from Rifle, Colo., to Soldier Summit, Utah. The beds from which oil may be distilled are not so thick in Utah as in Colorado, but recent work done in this region by D. E. Winchester has shown that a great quantity of this shale is available in Utah and that it may yet be a valuable source of petroleum when the fields that are now productive approach exhaustion. The white shale which occurs at Soldier Summit will yield on distillation at least 16.8 gallons of crude oil to the ton.

Where the Green River formation is first seen it dips to the north (right) 25° or 30°, but beyond the curve to the right, above the abandoned station of Tucker, on the old line, the beds are somewhat disturbed, and between mileposts 663 and 664 they are thrown into a well-marked synclinal fold, which may be seen on the right.

The siding of Detour marks the junction of the old and new lines and also the termination of this narrow part of the valley. Below Detour the valley is more open, at least as far as Narrows siding, where it is again constricted by the appearance of harder rocks.

Immediately below Narrows siding the lowest beds of the Green River formation rise downstream, and half a mile beyond milepost 672 the red beds of the Wasatch make their appearance beneath the gray beds of the Green River. The Wasatch is bright red, and the change in color is very striking. This outcrop of the Wasatch is very different in composition from that east of Soldier Summit. There it is generally clay or soft shale; here it is largely a mass of conglomerate composed of boulders of all sorts of rock that occur in the Wasatch Mountains. The presence of such masses of conglomerate made up of boulders of this size is a sure indication that the material was derived from high mountains and that it was not carried far by the streams before it was dropped to form great boulder beds that now are consolidated into massive rock. It therefore seems certain that a high range of mountains once existed in this region when the Wasatch formation was deposited in the early stages of the Tertiary period. This range must have been old as measured by the standard in this mountain region, whereas the present Wasatch Range is supposed to be comparatively young. These statements, however, are not so contradictory as they appear, for most mountain ranges have a complex history, involving many movements up and down, and the Wasatch may not be an exception. It may have had its beginning as a mountain range in early geologic time, but that old range may have been worn down to a rolling plain and later it may have been uplifted into a range like the present Wasatch. In fact, such changes may have occurred several times.

The conglomerate has been a formidable barrier in the pathway of the stream, and it therefore forms a canyon which is scarcely wider than the stream that occupies it and which has given rise to the name "Narrows" for the siding at its upper end. The conglomerate is 700 or 800 feet thick and forms the sides of the valley for several miles. The character of the rock, as well as its brilliant red color, gives to the canyon an individuality that distinguishes it from all the other canyons on the line.

Soldier Creek flows directly west, and the railroad takes a course toward a high mountain peak, one of the southern points of the

Wasatch Range, which lies due west of Thistle. The most southerly point of this range is Mount Nebo, a peak which lies so far to the south (left) that it is obscured by the low hills in the foreground.

The appearance of the valley improves in its lower course; more of the ground is irrigated, and there are indications that the train is approaching a town or a railroad junction. Just before reaching the station at Thistle there is a complete change from the soft rocks of the Wasatch formation to the hard blue limestone and red and gray sandstone of the Jurassic system, which form a decided constriction in the width of the valley.

The railroad turns abruptly north and is joined at Thistle by a branch line which traverses the rich Sanpete Valley and extends as far south as Marysvale. This valley was early settled by Mormon families sent out from Salt Lake City by Brigham Young for that purpose, and in 1849, in order to protect these outlying settlements as well as those in the Salt Lake Valley, the State of Deseret[76] was organized. The organizers passed through much the same experience as those who attempted to organize the State of Jefferson in what is now Colorado, but their motives were obviously quite different. The State of Jefferson was organized to protect the people and their property from the lawless hordes that would be attracted to the country by the discoveries of gold, whereas the State of Deseret was organized to protect and strengthen the Mormon Church by having the machinery of government controlled by the dignitaries of the church.[77]

Thistle.

Elevation 5,033 feet.
Population 417.
Denver 681 miles.

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[76] The word "Deseret" is taken from the Book of Mormon and means honeybee. It is written in the Book of Ether of the people who came over the great water from the old world to the new: "And they did also carry with them 'deseret,' which, by interpretation, is a honeybee." The honeybee, or rather the beehive, is one of the important symbols of the Mormon Church, and the word "deseret" is used as the name of the most influential church newspaper, the Deseret News.

[77] Bancroft, in his History of Utah (pp. 439–440), describes the situation as follows:

"Until the year 1849 the Mormons were entirely under the control of their ecclesiastical leaders, regarding the presidency not only as their spiritual head but as the source of law in temporal matters. Disputes were settled by the bishops, or, as they were also termed, magistrates of wards, appointed by the presidency. The brotherhood discountenanced litigation, but the population did not entirely consist of members of the church. There was already in their midst a small percentage of Gentile citizens gathered from nearly all the civilized nations of the earth. It was probable that, as the resources of the territory were developed, this number would increase in greater ratio, and it was not to be expected that they would always remain content without some form of civil government. Not infrequently litigation arose among the Gentiles, or between Mormon and Gentile; and though strict justice may have been

Soldier Creek, which the railroad has been following from Tucker, is here joined by Thistle Creek, and together the two streams form the Spanish Fork. The canyon at Thistle is narrow, and its walls are composed of bluish limestone on the east and banded red and gray sandstone or quartzite[78] on the west. The blue limestone contains marine shells which show that its age is Jurassic. It normally belongs beneath the Cretaceous rocks, which are so conspicuous along the railroad from Green River nearly to Kyune. Near Thistle the rocks dip steeply to the east, but toward the north the dip decreases until they lie nearly flat. They also change in character, for they become much softer downstream and are composed almost

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done by the bishops, it was difficult for the latter to believe that such was the case. * * * The Saints regarded their courts as divinely commissioned and inspired tribunals; but not so the Gentiles, by whom reports were freely circulated of what they termed the lawless oppression of the Mormons. Thus it became advisable to establish for the benefit of all some judicial authority that could not be questioned by any, whether members of the church or not, and this authority must be one that, being recognized by the Government of the United States, would have the support of its laws and the shield of its protection. Further than this, if the Mormons neglected to establish such government, the incoming Gentiles would do so ere long."

To accomplish this purpose a convention composed of "the inhabitants of the part of upper California that lies east of the Sierra Nevada Mountains" was called to meet in Salt Lake City on March 4, 1849. A constitution was drafted for the State of Deseret, which was defined as extending from latitude 30° to the border of Oregon, and from the Rocky Mountains to the Sierra Nevada, together with considerable territory that is now within the Republic of Mexico. A general election was held at Salt Lake City on the 12th of March, and Brigham Young was chosen governor of the new State. On July 2 the general assembly convened, and on the next day Willard Snow, being appointed speaker of the house of representatives, administered the oath or affirmation to the executive officers. Bancroft (History of Utah, p. 443) says:

"Thus did the brethren establish, in the valley of the Great Salt Lake, the State of Deseret. It was certainly a novel and somewhat bold experiment on the part of the Saints, mustering then little more than one-sixth of the number required for the admission as a State, thus to constitute themselves a sovereign and independent people, with a vast extent of territory, and calmly await the action of Congress in the matter."

On July 5 Almon W. Babbitt was elected delegate to Congress, and on the next day a memorial to Congress was adopted, asking for admission as a State. Babbitt proceeded to Washington, but Congress refused to recognize him as a delegate from a State which had no legal existence. The Territory of Utah was provided for by an act of Congress September 9, 1850, and President Fillmore appointed Brigham Young its first governor.

[78] Quartzite is a term applied to a sandstone that has been changed into a hard, dense flinty rock by the deposition around the sand grains of silica from percolating water carrying material of that kind in solution. A quartzite is much harder than a sandstone, is more resistant to the weather, and is generally nearly pure silica.

entirely of soft red shale with some beds of sandstone. Beyond milepost 681 this sandstone has been extensively quarried for building stone in Salt Lake City, but the growing use of cement has led to the abandonment of the quarries.

Spanish Fork is here joined by Diamond Fork, a stream coming from the northeast (right), which, though rather small, has been utilized by the United States Reclamation Service to bring water from Strawberry River, a tributary of Green River, through a dividing ridge, to irrigate some barren land in Salt Lake Valley.[79] The

FIGURE 59.—Map of Strawberry Valley reclamation project. The dash line shows the boundary of the Green River drainage basin.

water obtained by damming Strawberry River is carried through the ridge by a long tunnel and discharged into one of the head branches of Diamond Fork. From this point it flows by gravity into Spanish Fork and is diverted lower down, where it is most needed. The traveler may see the diversion canal near the lower end of the canyon.

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[79] The Strawberry Valley diversion (see fig. 59) is one of the large projects that the United States Reclamation Service has carried to a successful completion. By this project water that is not needed where it falls is taken over into another drainage basin and given to the thirsty land. As shown on the map (fig. 59) Strawberry River is one of the head branches of Duchesne River (du-shayne′), a stream that enters Green River from the west. Strawberry River heads in rather open country near the Wasatch Range, which has an average elevation of about 8,000 feet above sea level. At that altitude the cultivation of any but the most hardy grains and vegetables is impossible, so that the water is of little value where it falls, but over the

The Triassic red beds extend nearly a mile west of the mouth of Diamond Creek, to a place where they are probably terminated by a fault which separates them from the Carboniferous and older rocks that form the core of the Wasatch Range. The rocks of the mountains are of Carboniferous age but are so poorly exposed and so complicated in structure that it is useless to attempt to describe them. From some limestones of this formation comes the hot sulphur water which has made Castilla (cas-tee'yah) Hot Springs a noted resort.

Castilla.

Elevation 4,912 feet.
Denver 685 miles.

The Wasatch Mountains, although not equal in height to the Rocky Mountains of Colorado or the Sierra Nevada of California, are nevertheless one of the dominating ranges of the continent, and their peaks range in elevation from 10,000 to more than 12,000 feet. The impressiveness of the range is due more to its situation than to its elevation, but both unite to make it a noteworthy group of mountains. During the great ice age this range supported a number of glaciers (see the map opposite p. 244), but the glaciers were neither so large nor so numerous as those of the Rocky Mountains.

Since leaving Canon City the traveler has been either in the Rocky Mountains or in what is generally known as the Plateau country, so called because it is made up of a series of plateaus of different elevations, but when he passes through this canyon and emerges on the west front of the Wasatch Range he finds himself in a country that is very different from any that he has yet seen on this journey. This

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mountains on the west there is not sufficient water to irrigate all the land that is well adapted to farming. The problem, therefore, was to bring the water of Strawberry River across the divide to the lands that needed it so greatly. To accomplish this feat a dam 72 feet high was built across Strawberry River at a place called the "Narrows," a constricted point in the valley below a part that is open and well adapted to form a reservoir. A tunnel was then driven from one of the tributaries of Strawberry River through the divide for a distance of 19,897 feet (nearly 4 miles), so as to allow the water of the reservoir to flow through and discharge into the head of Diamond Creek, a tributary of Spanish Fork. The water flows down Spanish Fork to the west side of the Wasatch Mountains, where it is again diverted into a canal for utilization, first for the development of electric power and later for irrigation. The hydroelectric plant is 3½ miles below the diversion dam in Spanish Fork, and the power is generated by dropping the water to the level of that stream, as shown in Plate LXXXIX, *B*. The water is then carried to the south end of Utah Lake and distributed to the land at that place and also on the east side. This land has been partly settled since 1847 but has not been fully developed because of the shortage of water. The supply from Strawberry Valley will be sufficient to irrigate about 54,000 acres of this land, and thus a great addition to the productive power of the State is made at the expense of a very slight loss to that part from which the water is taken.

region is known as the Great Basin, a land of desert basins and of barren mountain ranges, which in general trend north and south. The precipitation here is slight, ranging in this latitude from 5 to 8 inches, and that which falls finds its way into some deep basin in the interior like Great Salt Lake, where the water, when it evaporates, leaves the mineral matter that is carried in solution to form beds of salt or soda.

The walls of the canyon, although steep, are generally smooth and are covered, except in the higher parts, by brush and dwarf trees of many kinds. In summer they are clothed in a soft, beautiful green, with here and there an evergreen tree to accentuate the softness of the foliage of the other trees, but in September, after the frost has touched the dwarf maples of the higher slopes, the coloring is magnificent. Many of the slopes are a blaze of scarlet from top to bottom, and others show scarlet interspersed with brown and green. The clumps of aspen give the landscape a touch of gold, and the whole scene presents an unexcelled splendor of autumn colors.

The canyon grows broader to the west, and the railroad is built along its north wall. On the opposite side, near milepost 687, is the headgate where the water of Spanish Fork, including that from Strawberry River, is diverted into a large canal, which is soon lost to view as it follows the south wall of the canyon to the mouth and there turns to the left to the area where its waters are most needed.

The outlet of the canyon is not like the outlets of most of the canyons that the traveler has seen but seems to be dammed or choked by a great mass of gravel. Where first seen, a little below the intake of the canal, the gravel is at railroad level, and its top is flat, as if it had been washed down the canyon and deposited as a delta in standing water. An examination of the opposite slope shows a terrace of similar material about 100 feet higher. This terrace also appears to have had a similar history, except that as it is the older of the two deposits most of its gravel was washed away when the second terrace was formed, and so only fragments remain where they have been protected on the side slopes. These terraces are of the greatest significance in the interpretation of the late geologic history of this region; to the geologist they have much the same value that the cliff dwellings or tables of cuneiform writing have to the archeologist. They constitute the record of one of the most remarkable geologic events in this country—the flooding of the basin of Great Salt Lake during the ice age to a depth of more than a thousand feet. When these terraces in the Spanish Fork canyon were formed the water of Lake Bonneville, as it has been called to distinguish it from the present lake, entered the mouth of the canyon at the level of the highest terrace, and if a traveler had then attempted to make a westward journey here he would have been confronted by an inland fresh-

water sea that extended from the Wasatch Mountains to the west line of the State.[80] (See fig. 60.)

Some of the most prominent of these old shore lines have been named. The highest, the one visible as a terrace about 100 feet above the track, is called the Bonneville shore line. The one at railroad level, which has not been named, represents a later stage of water, when the northern outlet had been cut down below its first position but not so low as it became later. It probably records the position of a harder bed of rock, which the outflowing waters encountered when they had partly cut the barrier that held them in place, and this hard bed held the stream so long that it permitted Spanish Fork to build at this height a delta of considerable extent.

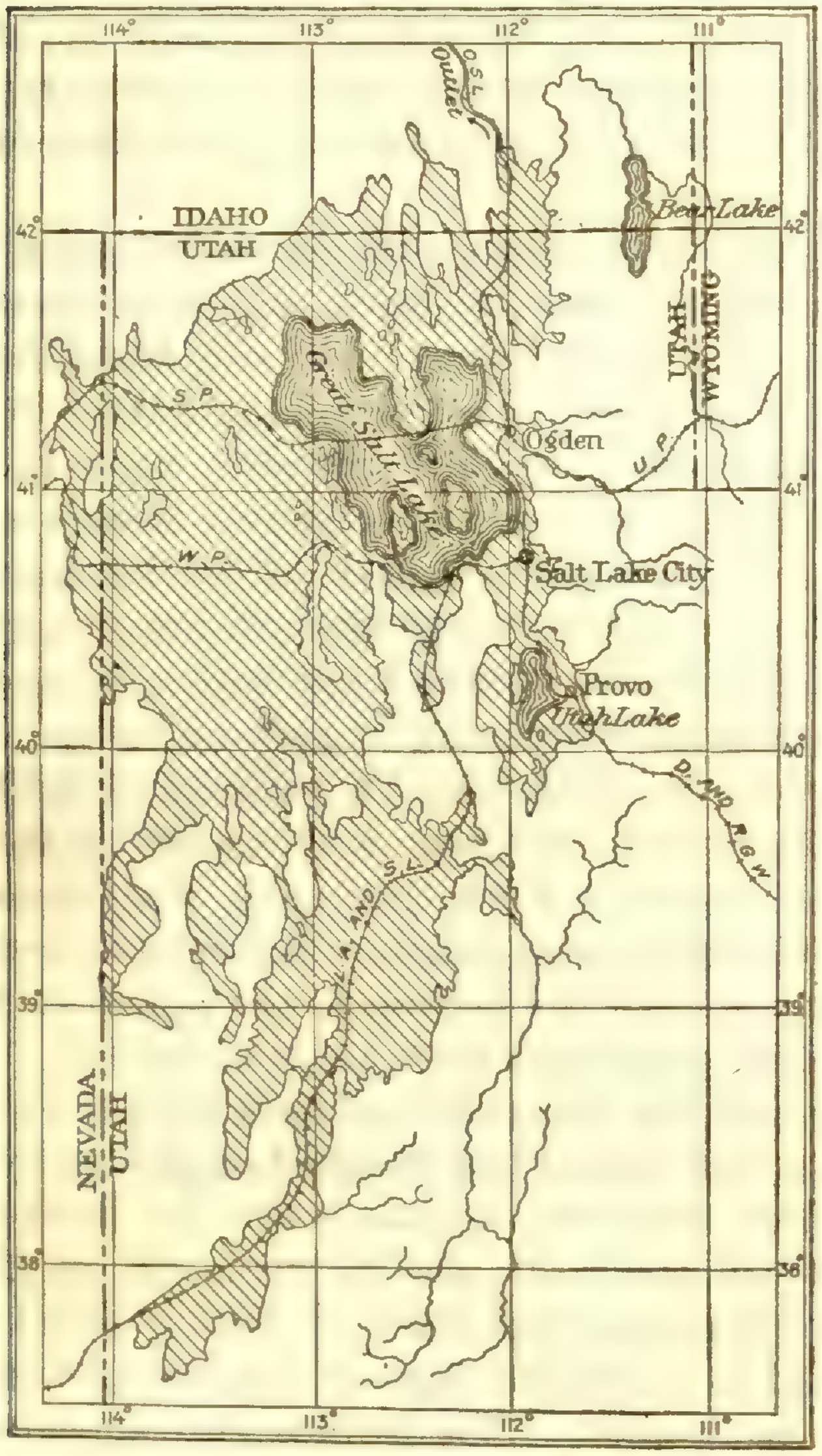

FIGURE 60.—Map of Lake Bonneville (the area indicated by diagonal shading).

In its descent to the lower level of the valley the railroad cuts deeper and deeper into the delta, and finally, near milepost 689, it comes out on a still lower plain, which represents a later and lower stand of the waters. This plain is extensive, and from its even surface the

[80] The Bonneville shore lines and broad flats that the traveler has already seen at the mouth of Spanish Fork canyon and the others that he will see before he reaches Salt Lake City will doubtless convince him that at some time long ago the drainage basin of which the present Great Salt Lake occupies only the deeper part was filled with water to the highest shore line, or about 1,000 feet. This old and vanished lake has been named Lake Bonneville, in honor of Capt. B. L. E. Bonneville, who in 1832 to 1836 explored much of the region formerly occupied by its waters.

The late G. K. Gilbert, who was recognized as the leading authority on the history of Lake Bonneville, said, in speaking of the highest shore line (U. S. Geol. Survey Mon. 1, pp. 94–99, 1890):

"If the Bonneville shore line were far less deeply engraved than it is it

A. BONNEVILLE SHORE LINE.

Lake Bonneville shore line as it is marked on the west face of the Wasatch Mountains at the mouth of Hobble Canyon, back of Springville. Above this line the rocks are bare, and there is no trace of wave action; below it the slopes are covered with mud washed into the lake when it stood at this height. Photograph by G. B. Richardson.

B. HYDROELECTRIC PLANT OF THE STRAWBERRY VALLEY RECLAMATION PROJECT.

After the water of Strawberry Valley is carried by a long tunnel through the Wasatch Mountains into Spanish Fork it is diverted into a canal and dropped several hundred feet to the plant shown in this view. The electric power which it generates is sold to near-by towns, and the water is then used for irrigating the land. Photograph by the U. S. Reclamation Service.

TIMPANOGOS PEAK.

Timpanogos Peak is one of the most prominent and beautiful peaks of the Wasatch Range. Like Pikes Peak it rises almost sheer from the edge of the plain, and the outlook from its summit is said to be magnificent. Provo River, a clear stream, cuts through the mountain on the right of the peak. Photograph furnished by the Denver & Rio Grande Western Railroad.

traveler may get his first general view of the Great Salt Lake basin. Originally this plain was only a desert, but now it is

would still be conspicuous by reason of its position. As it is, no geologic insight is necessary to discover it, for it is one of the pronounced features of the country. It confronts all beholders and insists on recognition. The tourist who visits Ogden and Salt Lake City by rail sees it on the Wasatch [Mountains] and on the islands of Great Salt Lake and makes note of it as he rides. The farmer who tills the valley below is familiar with it and knows that it was made by water; and even the cowboy, finding an easy trail along its terrace as he 'rides the range,' relieves the monotony of existence by hazarding a guess as to its origin."

Gilbert followed this shore line, studied it in detail, and mapped it throughout most of its sinuous course. The map copied from his report (see fig. 60) shows the greatest extent of Lake Bonneville as compared with the present Great Salt Lake.

The history of Lake Bonneville goes back to a time before man was known on the globe, or possibly about to the time of his first appearance, but in any event the conditions that led to the formation of that great body of water could not have been due to man's activities and hence must have been the result of climatic change. Gilbert (U. S. Geol. Survey Bull. 612, pp. 96–97, 1915) gives the history of Lake Bonneville as follows:

"The latest of the periods into which geologists divide past time witnessed a series of climatic changes which affected the whole earth, and * * * the element which recorded its changes most clearly was temperature. There were several epochs of cold, and they were separated by epochs of warmth. During the cold epochs the high parts of the Wasatch Range held a system of glaciers, and in one of them several ice tongues protruded so far beyond the mouths of the mountain canyons that they heaped their moraines on the floor of Jordan Valley, only a few miles from the place where Salt Lake City now stands. In that epoch of cold the rate of evaporation was far slower than now, and evaporation was at so great a disadvantage in its contest with precipitation that there was immense expansion of the water surface. When the lake was largest it was comparable in area and depth with Lake Michigan; it had eleven times its present extent. In attaining this great expanse the water surface rose to a position more than 1,000 feet above its present level.

"To this great body of water geologists apply a distinctive name—Lake Bonneville—and they have given much attention to its history, which is written in shore lines, deltas, channels, deposits, and fossils. The shore lines [Pls. LXXXIX, *A*, and XCVI, *B*] appeal most to the traveler and may be seen from car windows at several points.

"As a matter of definition a shore is merely the meeting place of land and sea, or of land and lake, but as a matter of land form it is much more. At the shore the lashing of storm waves works changes in the land, giving it new shapes. At some places the land is carved away; at others it is made to encroach on the water. Where it is eroded the limit of erosion is marked by a cliff, and below the water is a shelf of gentle slope. Where additions are made they take the form of beaches or bars, which rise little above the water level and are composed of sand or gravel. At some places a bar spans a bay from side to side; elsewhere it is incomplete, projecting from a headland as a spit.

"The waves of Lake Bonneville were as powerful as those of Lake Michigan and fashioned the shore into an elaborate system of cliffs, beaches, and spits, and when the waters finally fell to the

dotted with farms, each protected by a line of tall poplars that may be seen far across the valley. Utah Lake, a body of fresh water 30 miles long and 6 to 10 miles wide, lies in the middle of the basin,

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lower levels they left behind the shapes their waves had made. The base of each surviving shore cliff is a horizontal line, and so is the crest of each beach, bar, and spit, and these features in combination trace the outline of the old lake as a level contour about the sides of the basin and the faces of mountains that were once islands in the lake.

"In rising and falling the waters lingered at many levels, and so there are many ancient shore lines, but two of them are more conspicuous than the rest and have been named. The highest of all is the Bonneville shore line, and 375 feet lower lies the Provo shore line. The Bonneville line represents a relatively short stand of the water and is conspicuous chiefly because it marks the upper boundary of wave action. All the slopes below it have been more or less modified by the waves, but the slopes above it retain the shapes which had been given them by other agencies. The Provo line represents a long stand of the water and is conspicuous because it is strongly sculptured.

"In all the early history of the great lake its basin was closed, like that of the modern lake. The water surface rose and fell in response to climatic changes like that of its modern remnant. The last great rising was the highest and terminated the series of oscillations by creating an outlet. The lowest point of the basin's rim was at Red Rock Pass [130 miles by rail north of Salt Lake City], and when the water rose above that level the stream which began to cross the pass descended to Portneuf River, a tributary of Snake River, the chief branch of the Columbia. Through the creation of this outlet the Bonneville Basin, which had previously contained an independent interior drainage system, became part of the drainage system of the Pacific Ocean. * * *

"The formation at the summit [of Red Rock Pass] consisted of soft earth, and as soon as overflow began a channel was formed. The deepening of the channel increased the volume of the stream by lowering the outlet of the lake; the greater stream was more efficient in deepening the channel, and these two causes interacted until the stream became a stupendous torrent. The volume of water discharged before the flow became steady was enough to supply Niagara River for 25 years, but the record of the torrent's violence leads to the belief that it lasted for a much shorter period. * * *

"The draining of the lake down to the Provo level reduced its area by one-third and correspondingly reduced the quantity of water annually evaporated. Two-thirds of the inflowing water was then disposed of by evaporation, and the remainder was discharged through the outlet. Only a great change of climate could restore the balance between inflow and evaporation, and the change was slow in completion. At last, however, the pendulum of temperature swung far enough on the side of warmth. The outlet channel ran dry, the lake basin was again separated from the drainage system of the Pacific, and the lake began to shrink. So long as there was outflow the water was fresh, but when the outflow ceased there began that accumulation of salt which has made the water of the present lake a concentrated brine.

"At times in the history of the lake, especially while the Provo shore line was being formed, the tributary streams brought down sand and gravel, which they dropped at their mouths, building deltas. When the water fell these deposits remained as fan-shaped benches having steep fronts. The streams that built them then dug channels through them. * * *

and beyond it are the barren slopes of the Oquirrh Mountains (o'queer). Most of these desert ranges are not very high, but they are striking features, for they rise, island-like, out of a wide expanse of desert.

The plain upon which the railroad is built is another of the numerous unnamed terraces that mark the shore line of Lake Bonneville and represent pauses of longer or shorter duration in the gradual lowering of the water in the basin. This is well developed about the station of Mapleton. The view from the railroad at this point is particularly fine because it embraces what appears to be the bottom of the valley, so wide is it and so completely cultivated. On the right stands the great blank wall of the mountains, across whose front the Bonneville shore line (see Pl. LXXXIX, *A*) can be seen as a mere thread separating the slopes above—characterized by gashes cut by streams—from those below, in which all roughness and angularity have been concealed by the material deposited in the ancient lake. Along the foot of the slope, within the irrigated lands, stretches a belt of sloping plain on which most of the homes of the region are built. Each house has its protecting row of slender poplar trees, which give the scene an aspect so foreign that one seeing it might almost imagine himself on the plains of northern Italy looking at the slopes of the Alps, instead of in the Salt Lake Valley looking at the slopes of the Wasatch Mountains.

Mapleton.
Elevation 4,724 feet.
Population 586.
Denver 691 miles.

The abrupt change from the steep slope of the mountain front to the nearly flat surface of the desert plain, except where deltas and bars were built in the waters of old Lake Bonneville, is very striking and doubtless will attract the attention of many travelers. The traveler sees no foothills, no indication of a mountain front, until he reaches the foot of the slope. What does the abrupt change from mountain to plain mean, and has it any connection with the geologic history of the region? It assuredly has a meaning, and the processes that produced these mountains have had a most striking effect in determining not only the surface features of this region but its climate and its arid conditions. Long ago, as man measures time, the rocks composing the crust of the earth broke along a line that now coincides with the west front of the Wasatch Range, and the

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"In quality of water and in temperature Lake Bonneville was as well fitted for abundant and varied life as the Bear Lake to-day, and though the only remains yet found in its sediments are fresh-water shells, we need not doubt that its waters teemed with fish. We may confidently picture its bordering marshes as fields of verdure and its bolder shores as forest clad; and we may less confidently imagine primitive man as a denizen of its shores and an eyewitness of the spectacular deluge when its earthen barrier was burst."

part on the east side of that break or fault was forced up many thousand feet, or the part on the west was dropped an equal distance, or both movements took place to a lesser degree. It matters not which side moved, for in any event the part east of the fault now forms mountains because it was uplifted relative to the other, or the other is now a low basin because it was depressed relative to the part on the east.[81] Although the principal movement probably took place long ago, slight movements have occurred so recently that they have broken across alluvial cones formed by small streams flowing out of the mountains.

A short distance beyond Mapleton the railroad curves to the right and approaches the edge of the plain. There it begins to descend to a lower plain, which stretches away in the distance as far as the eye can see. Before reaching the level of the lower plain the railroad passes through the flourishing town of Springville (see sheet 10, p. 244), which is surrounded not only by fields of grain, alfalfa, and sugar beets but by orchards that stretch out mile after mile until they seem to be interminable. It is indeed a land of peace and plenty, and an added beauty is given to the scene by the still waters of Utah Lake shimmering in the bright sunshine. A branch

Springville.

Elevation 4,555 feet.
Population 3,010.
Denver 696 miles.

[81] The entire Great Basin, which extends from the Wasatch Range on the east to the Sierra Nevada on the west, is characterized by faulted mountains like the Wasatch. Such mountains are generally known as "block mountains," for the reason that the crust of the earth has been broken into great blocks by the faults and later these blocks have been tilted in different directions. In the central part of the basin the faults and consequently the block mountains trend north and south, as may be seen on any good map of the region. The beds of rock of which such a mountain is composed may originally have had a simple structure or they may have been folded and broken in a most complex manner. But no matter how complex the folding the block has acted as a unit and has been tilted in the same manner as the horizontal rocks.

In the tilting the edge of the great block that was elevated produced a mountain and the edge that was depressed formed a deep basin, which later was partly filled by sand and gravel washed in from the surrounding slopes. In many places the loose rock filling has a depth of more than a thousand feet. Such a basin is generally deepest in the center, and the slight precipitation that falls on the surrounding slopes finds its way to the lowest point, where it forms a shallow lake, but the water is soon carried off by evaporation and there remains in its place only a dry lake bed, known in the Southwest by the Spanish name of "playa." The entire basin is also frequently spoken of as a "bolson" (bowl-sown'), a Spanish name meaning purse, which has been applied to the basin because it resembles in shape a Spanish purse.

Great Salt Lake is said to lie in such a basin, though it really lies in several basins, which are so shallow that the water extends from one to the other. In time of drought it too would disappear were it not for the large supply of water it receives from the high ranges on the east.

GEOLOGIC AND TOPOGRAPHIC MAP
OF THE
RIO GRANDE ROUTE
From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
GEORGE OTIS SMITH, DIRECTOR

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M. R. CAMPBELL, Geologist
C. H. BIRDSEYE, Chief Topographic Engineer
A. C. ROBERTS, Topographer

1922

EXPLANATION

		Age	Thickness in feet
B	Lake Bonneville at its highest stage and the sediments deposited in its waters	Pleistocene	
E	White shale and sandstone (Green River formation)	Tertiary (*Eocene*)	2,600
F	Red shale, sandstone, and coarse conglomerate (Wasatch formation)	Tertiary (*Eocene*)	1,500
H	Sandstone, shale, and coal beds (Mesaverde formation)	Upper Cretaceous	1,400
J	Dark marine shale (Mancos shale); in lower part sandstone (Ferron sandstone member, Fer)	Upper Cretaceous	3,600
M	Brown sandstone (Dakota sandstone)	Upper Cretaceous	40
N	Variegated shale and sandstone (McElmo formation and La Plata sandstone)	Cretaceous? and Jurassic	1,800
O	Limestone and sandstone	Jurassic	
P	Bright-red sandstone and shale	Triassic	
Q	Limestone, sandstone, and shale	Carboniferous	
	Fault		

railroad turns to the south (left) and runs to the Tintic mining district, 43 miles distant. The town was named Springville because of a large hot spring which issues from the base of the mountain in Hobble Canyon just east of the town. This spring and the stream into which it flows provide an unfailing supply of pure water for the State fish hatchery, which is about a mile from the town on the right of the track.

East of Springville the Bonneville shore line is beautifully developed on the mountain front (see Pl. LXXXIX, *A*); above it the normal mountain slopes appear, but below it all is covered with the sediment deposited in the old lake.

In a short distance the railroad descends to the lower plain, which it follows to the town of Provo. The shore line in this vicinity is remarkably well preserved and has been named the Provo shore line. At Provo a branch line of the railroad turns directly through the town and the well-irrigated farms to the north and ascends Provo Canyon, which cuts across the Wasatch Range. The canyon winds about the base of Timpanogos Peak, on the north, and here many views of this beautiful peak may be obtained. (See Pl. XC.) The branch line is 26 miles long and terminates at the Mormon town of Heber, which is beautifully situated in one of the level mountain valleys at an elevation of 5,559 feet above the sea.

Provo.

Elevation 4,512 feet.
Population 10,303.
Denver 701 miles.

Provo, one of the wealthiest of the Mormon towns, has large manufacturing industries. The following description of the town is given by Stanley Wood:

> This pretty little city belongs to the best type of Mormon towns, and a description will serve to give the reader a good idea of the characteristics of all the towns built by the Mormons. The dwellings as a rule are comfortable but not imposing in appearance. Many of them are constructed of adobe or sun-dried bricks, and all are situated in lots of generous proportions and surrounded by ornamental and fruit trees. Water for irrigating purposes flows down each side of the streets, and shade trees in abundance and of luxuriant growth render the walks cool and inviting. Gardens filled with fruit, flowers, and vegetables are the rule, and a quiet, peaceful, industrious, semirural life is the good fortune of the residents here. * * * Provo River furnishes excellent water power, while inexhaustible supplies of artesian water are to be found at a depth of from 40 to 200 feet. The city has, in fact, the finest water supply in any section of Utah. Provo has an excellent public-school system and is the seat of the Brigham Young Academy, which was amply endowed by the first president of the Mormon Church, from whom the school takes its name. Its churches and public buildings, including an opera house, are a credit to its people, who are of a literary taste and inclined to liberality of thought.

One who is not familiar with the development of the Salt Lake Valley can hardly realize that it was first settled little more than 70 years ago, when there were no green spots in the valley except where the mountain streams first spread their waters out upon the valley

floor and when most of its surface presented to the eye only the dull gray of the desert. To Brigham Young and the first Mormon settlers must be given credit for far-sighted vision and steadfastness of purpose in carrying out their plan of making this land, where the conditions seemed so unfavorable, a rich agricultural region. Who to-day, without capital other than brains and muscle, would care to undertake the task of making homes in such a place?

In the vicinity of Provo the traveler may have many fine views of the towering wall of the Wasatch Range, deeply cut by canyons and crowned by some of the highest peaks in the region. A little to the north stands the monarch of them all, Timpanogos Peak (Pl. XC), whose barren rocky walls tower 11,057 feet above sea level, or nearly 1¼ miles above Provo station. In this western country mountains of this height are not uncommon, and the traveler in his trip across Colorado has seen many that are higher, but seldom can one look from a plain at a wall-like mass such as Timpanogos, whose front is unbroken by cleft, ravine, or spur. The great mass is awe-inspiring, and whoever sees it can only wonder how it was uplifted and whether the movement was rapid enough to have been perceptible had man been there to witness the uplift.

At Provo the Denver & Rio Grande Western Railroad is paralleled on the left by one of the lines of the Los Angeles & Salt Lake Railroad, which divides at Lynndyl; the main line keeps to the west through Stockton and comes into Salt Lake City from the west, and the other, a subordinate line, turns to the east through Nephi and Provo and enters Salt Lake City from the south. Provo is also connected with Salt Lake City by an interurban trolley line, which may be seen on the right on the outskirts of the town.

The country between Provo and Utah Lake is not only well supplied with water from the mountain stream but also has many flowing wells, which are used extensively for irrigation. Many of these wells may be seen from the passing train not only about Provo but also as far west as Lehi.

Two miles out of Provo the railroad crosses Provo River, which heads far to the east in the Wasatch Mountains and reaches the low plains and Utah Lake on the west through Provo Canyon. About 5 miles from Provo the Los Angeles & Salt Lake Railroad crosses the Denver & Rio Grande Western and continues on the east side to Salt Lake City.

From Provo to Lehi the railroad takes a northwesterly course, following closely the shores of Utah Lake.[82] At first the lake is a

[82] Utah Lake is 30 miles long and 6 miles wide at its widest point. Its supply of water is derived from the mountain streams, American Fork, Spanish Fork, Provo River, and Salt, Peteetweet, and Hobble creeks. It is not salt like many of the desert lakes that have no outlet, but its surplus waters flow through Jordan River into Great Salt Lake.

mile distant, but farther to the northwest the railroad approaches more and more closely, until at the siding of Geneva the waters come to the right of way. The lake is very shallow, and consequently bathers can go out a long distance without danger of entering water beyond their depth.

From Provo to Lehi the railroad passes through some of the best farming land in the valley, and orchards and fields of grain, alfalfa, and sugar beets are on every hand. After passing the point of the lake the next object of interest is the great sugar mill on the right in the suburbs of Lehi. Not only are the beets crushed and the syrup extracted here but much syrup is refined that is produced at other plants and pumped here through long pipe lines. The town abounds in shade and fruit trees, which give it a very pleasing and restful appearance, especially when seen on a hot midsummer day.

Lehi.

Elevation 4,550 feet.
Population 3,078.
Denver 717 miles.

East of Lehi the foot of the mountain is 5 or 6 miles from the railroad, but north of the town the mountain bends suddenly to the west and a long spur is thrust out into the middle of the valley. This

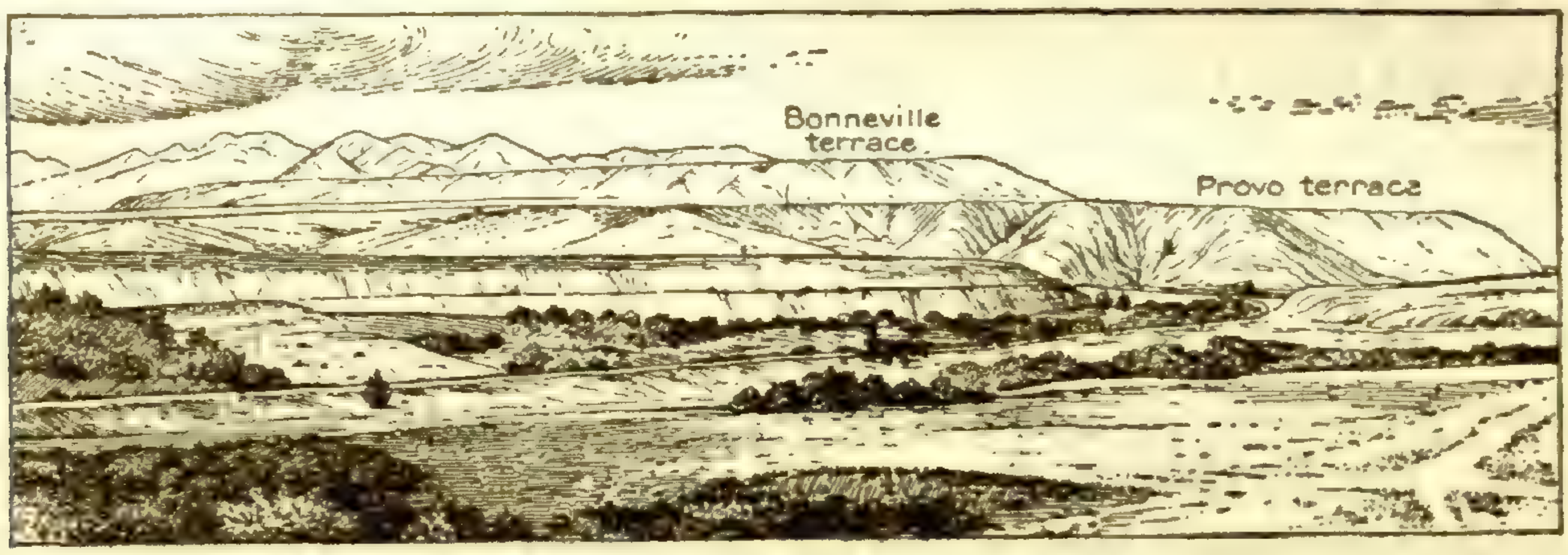

FIGURE 61.—Provo and Bonneville lake terraces at the Narrows of Jordan Valley, looking southeast.

long spur on the west face of the Wasatch Range is matched by an equally long, low spur which projects eastward from the Oquirrh Range, nearly cutting off the valley of Jordan River. These projecting points are merely remnants of a lava flow (andesite) that long ago, in Tertiary time, probably filled the valley from the base of one range to the base of the other. This flow may indeed have originally dammed Jordan River, forming a large lake, but if so the river later succeeded in cutting through the barrier a channel that is now known as "The Narrows." During the existence of Lake Bonneville these barriers of lava caused the currents in the lake to set in certain directions, and large quantities of gravel and sand were deposited around and over them in the form of bars or beaches. These terraces, as they appear from the northwest, are shown in figure 61.

Just before reaching Mesa siding (milepost 716) the Denver & Rio Grande Western crosses first the interurban trolley line, which spans

Jordan River and proceeds northward along the west side of that stream, and second a branch of the Los Angeles & Salt Lake Railroad, which connects the line running down Salt Lake Valley with the main line at Boulder south of Stockton. The Denver & Rio Grande Western Railroad descends at a steep grade, and at milepost 721 it runs on the right bank of Jordan River, which has gravel bluffs rising more than 100 feet on both sides. The top of the first terrace (about 250 feet above the river), which is crossed by the Los Angeles & Salt Lake Railroad, corresponds with the Provo shore line and doubtless was a gravel bar built out across the channel when the waters of the lake stood at the Provo level. The material composing these terraces is well shown in the numerous cuts of the Denver & Rio Grande Western Railroad and the trolley line across the river and in an immense gravel pit open on the right at a siding called Nash, at the lower end of the Narrows. At this place several large flumes on the left take water from Jordan River and distribute it over the low plain to the north.

The river valley below the Narrows is well farmed and makes a pretty picture as the traveler catches glimpses of it here and there, but the river swerves to the west away from the railroad and the traveler sees it no more. Near the siding of Olivers the railroad emerges upon the plain and the traveler has spread before him on the right the south end of the broad valley in which Salt Lake City is situated, bounded by the great wall of the Wasatch Mountains, as shown in Plate XCI. Here again the shore lines of Lake Bonneville are the most conspicuous features of the landscape. The traveler may readily follow the uppermost or Bonneville shore line by the slight horizontal line across the mountain front which separates the more rugged slopes above from the smoother and more gentle slopes below. Below the Bonneville is another shore line, which in some respects is much more prominent, as it is represented by the uppermost terrace or the great bar built out from the mountains to the east. Below this bar is the terrace which was made when the lake stood at the Provo level and which is crossed by the Los Angeles & Salt Lake Railroad in its course from Salt Lake City to Provo. These terraces are shown in figure 61.

On the left stands the Oquirrh Range in all its barrenness. The traveler may think that this range is the very type of desolation and of worthless barren rock, but if the atmosphere is clear and he studies the mountain carefully, he may see smoke arising from a canyon nearly opposite the station of Riverton, and he may be surprised to learn that in this canyon is the largest copper mine in Utah and, when the method of mining is considered, probably the most

Riverton.

Elevation 4,408 feet.
Denver 729 miles.

wonderful mine in the world. This is the Bingham mine, in Bingham Canyon, a description of which is given on pages 255–259.

North of Riverton the plain upon which Salt Lake City is built stretches to the foot of the terrace at the base of Ensign Peak and eastward to the foot of the mountains. Everywhere in this wonderful valley there are now fine farms, with trees, and in places there are manufacturing plants of different kinds. To-day it is a land of plenty, but it was not so on that memorable 24th of July, 1847, when Brigham Young and his band of faithful followers first looked out over this same valley from the mouth of Emigration Canyon.[83]

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[83] The early history of Utah is a history of the Mormon Church and people, their endeavor to find a home where they would be at liberty to establish their church and social customs without interference and persecution, and the resolute courage of their leading men, who faced the hardships of mountain and desert that they might carry out what was to them the will of God. The tale is fascinating and should be read by all who wish to know something of the early struggles of this people and of the great and wealthy State which they have been largely instrumental in producing.

The story has been simply told by Levi Edgar Young, grandnephew of Brigham Young, and the writer can do no better than to quote his words:

"The first permanent settlement in Utah was made at Salt Lake City by a band of Mormon pioneers from the State of Illinois. This was on July 24, 1847.

"During the winter of 1845–46 the Mormons were making extensive preparations to leave the city of Nauvoo, in the State of Illinois, and to make homes somewhere in the Far West. Their leader [Joseph Smith] had been killed, their property ruined by people not of their religious faith, and, convinced that they could not make a home in Illinois, they had but one recourse—they could move to lands farther west. * * * The Mormons collected all the wheat, corn, bacon, and potatoes that they could and exchanged their land for cattle, horses, and wagons. On February 10, 1846, the first team crossed the Mississippi, and in a few weeks Nauvoo was deserted.

"The Mormons slowly wended their way across the Territory of Iowa and established winter quarters on the banks of the Missouri nearly opposite Council Bluffs. Here they sojourned during the winter of 1846–47. They built 700 log cabins and 150 dugouts. * * * At Winterquarters and Kanesville, the two chief camps on the Missouri, about 12,000 people were gathered during the winter. Many died of cold and hunger, for the season was severe. * * *

"The first company of pioneers under Brigham Young left winter quarters in April, 1847. There were 143 men, 3 women, and 2 children. They struck off due west and upon reaching the Platte River continued along its north bank. * * * The company was well organized. Every morning at 5 the bugle sounded to awaken the camp. All assembled for prayers, then took breakfast, and the second bugle was sounded when the company began to march. * * * In June they reached the Black Hills and Fort Laramie. From here they followed the Oregon trail through South Pass to Fort Bridger. There they were given some idea of the kind of country in the vicinity of the Great Salt Lake, but as to the fertility of the soil everyone was doubtful. From Fort Bridger the party went through Echo and Emigra-

Then it was a desert covered with stunted sagebrush and greasewood, except in places where the mountain streams furnished a supply of water.

The train runs along through the valley, with good farms on both sides and the bare walls of the mountains as a background, until it reaches the next station, Midvale, which is the junction point of branch lines running to Bingham, 14 miles to the west. At Midvale is a large mill and lead smelter built for the reduction of some of the ores of the Bingham district. This smelter is known as the smokeless smelter, for it was one of the first smelters to recover and utilize the substances contained in the

Midvale.
Elevation 4,365 feet.
Population 2,209.
Denver 735 miles.

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tion canyons to the Salt Lake Valley. Orson Pratt, Erastus Snow, and some others were sent ahead and entered the valley of the Great Salt Lake July 21. They explored some parts and on the 23d staked off land and turned the waters of City Creek onto the soil. This was the beginning of irrigation in the West. The main party, under Brigham Young, arrived on July 24, and it is out of respect for him and the main company that this day is taken as Utah's natal day. * * *

"The pioneers settled on the present site of Salt Lake City. The first camp was made about where the Knutsford building [Auerbach's department store] now stands at the corner of Third South [Broadway] and State streets, on the banks of City Creek. * * * At a conference held on August 22 it was decided to call the town Great Salt Lake City. * * * Wilford Woodruff says in his journal: 'We have laid out a city 2 miles square and built a fort of hewn timber and of sun-dried bricks or adobe. This fort incloses 10 acres of ground, 40 rods of which are covered with blockhouses.' [This was called Old Fort and stood on what is now known as Sixth Ward Square, or the park near the Denver & Rio Grande Western Railroad station, now called Pioneer Square.]

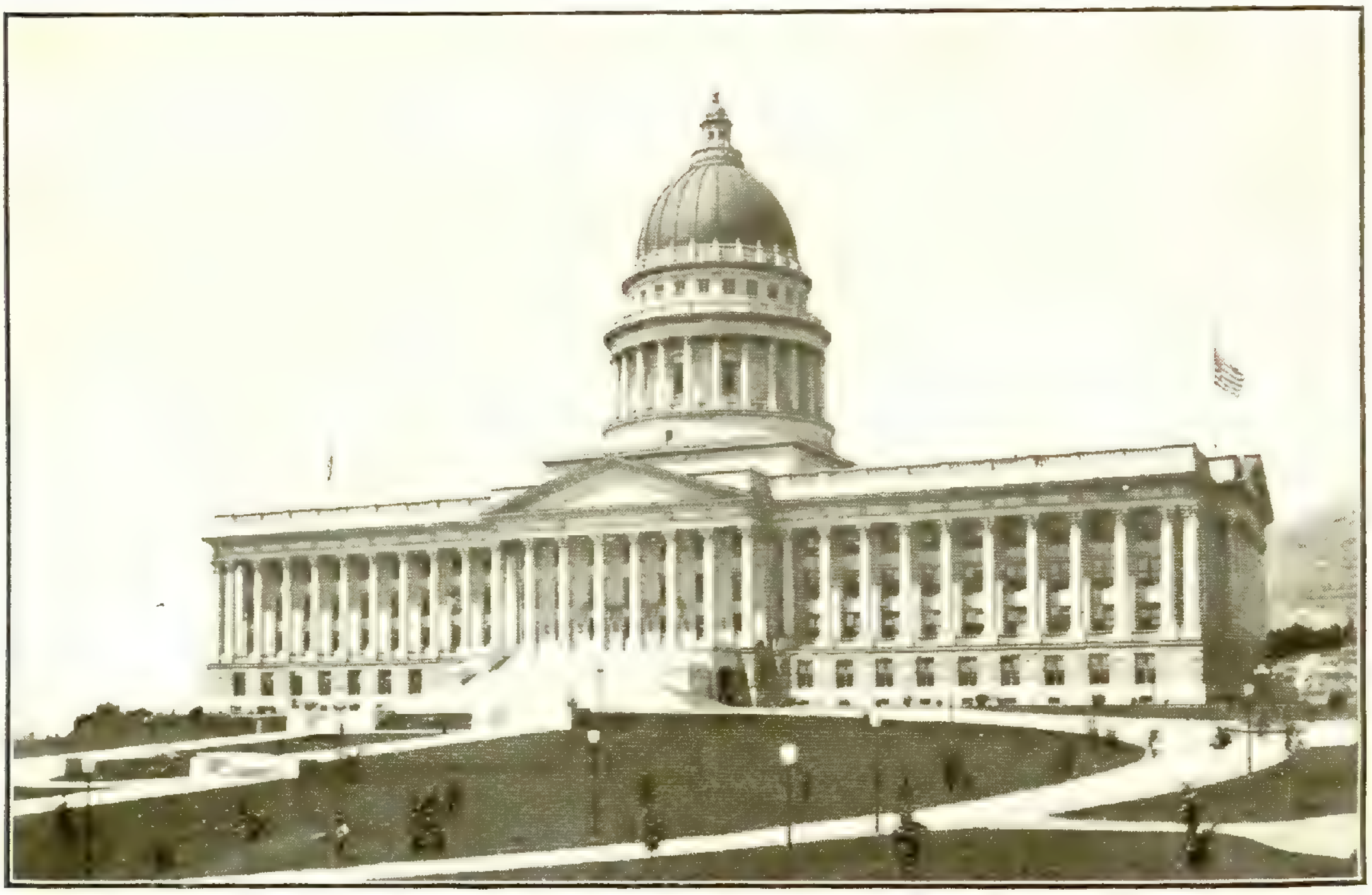
"After the first company, headed by Brigham Young, left for the Rocky Mountains, extensive preparations were made for others to follow. The 'First Immigration,' so called, consisted of 1,553 souls under the command of Parley P. Pratt. It left winter quarters on July 4, 1847. * * * There were 580 wagons, 2,213 oxen, 124 horses, 887 cows, 358 sheep, 35 hogs, and 716 chickens. This company arrived in Salt Lake City on September 19. By the end of the year some 4,000 people had settled in the valley of the Great Salt Lake.

"One of the saddest episodes in the history of Utah is the story of the handcart companies. Every year thousands of people from Europe and America gathered at the Missouri River points en route to Utah. * * * How to bring them across the plains was a problem. * * * There was not enough money to provide transportation by wagon for such a multitude, so Governor Young hit upon a unique plan. * * * [The plan was to make handcarts and have the emigrants push them across the plains, with a cow or two for every ten persons.]

"The plan was put in operation in the spring of 1856 and worked well for those companies that started early enough to reach Salt Lake City before winter. In the early autumn of 1856 three large companies of nearly 500 people each arrived in the valley of the Great Salt Lake. They had tramped more than 1,300 miles from Iowa City to Salt Lake City, drawing

WASATCH MOUNTAINS.

The Wasatch Mountains have a very bold and rocky face on the west, and when the tops are covered with snow they make a very striking picture. This view is taken from the level valley floor a short distance south of Salt Lake City. Photograph by Shiplers, Salt Lake City.



A. STATE CAPITOL OF UTAH.

On the high terrace north of the city stands the beautiful new granite Capitol of Utah. It overtops all the business houses below and can be seen from almost all parts of the valley. Photograph by Shiplers, Salt Lake City.

B. EAGLE GATE AND LION AND BEEHIVE HOUSES OF BRIGHAM YOUNG.

The most interesting features in Salt Lake City are the buildings and institutions of the Mormons. This view shows the famous Eagle Gate, erected by Brigham Young in 1853, and the Lion and Beehive houses, where several of his wives lived. Photograph furnished by the Denver & Rio Grande Western Railroad.

gases, which usually go off into the air to poison and kill vegetation. (For further information regarding smelters, see pp. 252–254.) At several places along the line the traveler may obtain glimpses of the Wasatch Mountains, and at almost every place he will see the Bonneville shore line as a faint line across the mountain front or the Provo shore line marked by great terraces or embankments of gravel.

The smelting industry has for many years been an important one in the Great Salt Lake Valley, and many smelters have been built at or near the station of Murray. Many of these smelters have been abandoned or consolidated, so that only one now remains—the Murray smelter, of the American Smelting & Refining Co., which may be seen on the right from the train. This plant smelts only silver-lead ores, and the great bulk of the copper ores from the Bingham mines are being treated at the Garfield smelter, the smoke of which may be seen rising over the extreme northern point of the Oquirrh Range on the west (left).

Murray.

Elevation 4,310 feet.
Population 4,584.
Denver 739 miles.

The most prominent object seen by one approaching Salt Lake City from the south is the new State Capitol (Pl. XCII, *A*), which stands on a commanding terrace north of the city, directly beneath Ensign Peak. The tall buildings also attract attention, though they are not particularly different from tall buildings in other cities. A little farther to the right the traveler may notice the large letter U on the mountain slope far back of the city. This letter was put there by some class of the University of Utah, which stands on the terrace directly beneath it.

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their supplies in handcarts. * * * For pluck and endurance this is a record that has rarely been equaled.

"Five companies in all undertook the journey that first year, but the two that started last had a dreadful time. James G. Willie commanded one and Edward Martin the other. They had been delayed in leaving the Missouri River and were caught in the piercing blasts of winter on the Platte and Sweetwater. * * * Some of the handcarts broke down; sickness and lack of proper food dispirited the marchers. * * * Thinly clad and poorly fed they labored on and on, and then they were put on half rations when not more than half of the journey was completed. Despair seized them. The company under Edward Martin made a camp in a ravine between the Platte and the Sweetwater in the latter part of October. Food became so scarce that the marrowless bones picked up from the prairies were boiled for soup. * * *

"Brigham Young received word of the sufferings of the emigrants on the plains. He immediately sent a company of the strongest men with wagons and supplies under the command of Joseph A. Young. This rescue party found the companies in a most miserable condition, fed them, and brought them to Salt Lake City. That is, they brought the survivors, for 250 * * * had died on the plains.

"During the four years extending from 1856 to 1860 more than 4,000 emigrants crossed the plains in this manner, and the total number of deaths was less than 300."

On the same terrace, but a little to the right, may be seen the buildings of Fort Douglas, which has been occupied continuously as an army post since 1862. Still farther to the right is the rather insignificant Emigration Canyon, down which Brigham Young's party came on July 24, 1847, and took possession of the valley. (For a description of the route followed by the pioneers, see p. 248.)

Many travelers unfamiliar with this region imagine that Salt Lake City stands on the shore of Great Salt Lake, but in fact the nearest point of the lake is 10 miles distant. The site of the city was chosen not because of its nearness to the shore of the lake, but because of the abundance of fresh water which comes from the mountains. The city, however, appreciates the value for recreation of such a body of water as Great Salt Lake, and a pavilion called Saltair has been built at the beach, which affords bathing facilities to those who wish to try a dip in the heavy waters (Pl. XCIV, *B*). It is a popular resort, easily reached by electric train during the season. Saltair is described more fully on page 244.

The next stop in this journey is at the new passenger station of the Denver & Rio Grande Western Railroad in Salt Lake City, the metropolis of the Great Basin and the home of the hierarchy of the Church of Jesus Christ of Latter-day Saints, more commonly known as the Mormon Church.

Salt Lake City.
Elevation 4,224 feet.
Population 118,110.
Denver 745 miles.

Salt Lake City, the capital of the great State of Utah, is in the eastern part of the Great Basin, at a point where several routes of travel from the Pacific coast converge into main eastern trunk lines. It has direct connection with Los Angeles on the southwest by the Los Angeles & Salt Lake Railroad; with San Francisco on the west by the Western Pacific and Southern Pacific railroads; with Portland and Seattle on the northwest by the Oregon Short Line and the Oregon Railroad & Navigation Co.'s line; with Butte and Helena on the north by the Oregon Short Line; and with the East by the Denver & Rio Grande Western and Union Pacific railroads. The Union Pacific trains run over the tracks of the Oregon Short Line to Ogden, and the Denver & Rio Grande Western main line also extends to Ogden.

Salt Lake City is the center of a large and prosperous metal-mining district; it has almost unlimited fuel resources in coal fields that lie 100 miles to the southeast, and it stands in the midst of a rich agricultural region that can supply food for many times its present population.

The general traveler, however, will find the chief interest in Salt Lake City in the Mormon people, their mode of life, and the peculiar institutions they have built up.[83a]

[83a] See footnote 83, p. 237.

On July 24, 1847, Brigham Young, at the head of the Mormon pioneers who had traversed the plains and hewed a way through the mountains, as he stood on the foothills after he had emerged from the rocky walls of Emigration Canyon, uttered these memorable words: "This is the place." This statement determined the location of Salt Lake City. Wilford Woodruff in his journal says:

> We gazed in wonder and admiration upon the vast valley before us, with the waters of the Great Salt Lake glistening in the sun, mountains towering to the skies, and streams of pure water running through the beautiful valley. It was the grandest scene that we had ever beheld till this moment. Pleasant thoughts ran through our minds at the prospect that not many years hence the house of God would be established in the mountains and exalted above the hills; while the valleys would be converted into orchards, vineyards, and fruitful fields; cities erected in the name of the Lord, and the standard of Zion unfurled for the gathering of the nations.

The pioneers began at once to cultivate the land, but before any of the land was assigned the city was laid out essentially as it is to-day. As each square was planned to contain 10 acres the present city blocks are very long, and one may walk a mile without crossing many of the city streets.

Until about 1871 Salt Lake City was strictly Mormon, but with the development of the railroads and mines Gentiles began to flock in, and to-day the city is thoroughly cosmopolitan.

The chief point of interest to the general traveler is Temple Square (see Pl. XCIII), the center or nucleus around which the city was planned and built. This square contains the temple, the tabernacle, and several other minor buildings. The exterior view of the Mormon temple is familiar to most persons. The temple was built of granite obtained in Little Cottonwood Canyon, about 20 miles southeast of the city. It was 40 years in building, and each stone was selected with the greatest care, so as to avoid flaws that might ruin the building in later time. The walls are said to be 9 feet thick and are built throughout of solid granite, and the height to the top of the angel Moroni is 222 feet. As the construction was begun before the days of the railroad most of the stone was hauled by ox team. In view of the fact that it was built without the aid of an architect, the result is surprising, for the temple is indeed an imposing structure and one that would attract attention and command respect and admiration anywhere. No one save the elect of the church is permitted to enter the temple, so that it has an air of mystery which to most persons is an added attraction.

The tabernacle, designed as the assembly room for the church conferences, is even more wonderful than the temple. It has a seating capacity of 8,000, but occasionally 12,000 persons have been crowded into it. It was built in the early days, when the people

were poor and before the advent of the railroad, and so perforce it was built with home-made materials and by the members of the Church. The roof is the wonderful part of the tabernacle—it was built entirely of wood and is without a single supporting column. The wooden trusses are held together by wooden pins and in places are bound by rawhide. The building is elliptical in shape, 250 feet long, 150 feet wide, and 80 feet high. The acoustic property of the tabernacle is perhaps its most wonderful feature. The dropping of a pin may be heard distinctly the entire length of the building—more than 200 feet. In the belief of the Mormons the architect of these buildings was God, and all their wonderful features are directly due to His beneficent direction.

Many persons are attracted to the tabernacle each week day at noon to hear the organ recitals, which are given free for the entertainment of visitors in the city. The organ, like almost all other parts of the tabernacle, was built before the days of railroad transportation, and so most of its parts were manufactured on the spot. Recently it has been rebuilt, without, however, changing the architectural effect, and now it is said to be the largest organ in the world. The total number of pipes is between 7,000 and 8,000.

Temple Square is a delightful park in the heart of the city, and with its flowers, trees, and greensward it forms a beautiful setting for the massive buildings. One of the most attractive and interesting monuments recently added to this park is that of the Sea Gulls (see Pl. XCIV, *A*), which was designed by Mahonri M. Young, a grandson of the great pioneer leader. This monument commemorates an incident in the experience of the early pioneers which shows their implicit faith in the protecting power of God. The gulls which inhabit the shores and islands of Great Salt Lake are held in high regard, if not reverence, by the Mormon people, for the reason that they saved the pioneers from starvation in the early days. As the story is extremely interesting it is given in full, as narrated by those who are supposed to know.

The pioneers reached the valley in the summer of 1847 with few personal possessions besides those which they carried on their backs. They at once made preparations to plant, so that the colony might have food for the coming year, but as they arrived in midsummer little could be grown that year. The next spring 5,000 acres of wheat were planted, and the prospects seemed good for an abundant crop. During the last week in May, however, the black crickets began to attack the growing wheat, as well as everything else that was green. At first the crickets were confined to certain fields, but soon they spread, and in a few days they had swept much of the valley.

As soon as the extent of the impending calamity was realized the people began to fight the common pest at every point. They drove

TEMPLE SQUARE, SALT LAKE CITY.

The central point in the plan of Salt Lake City is Temple Square, which is a beautiful park containing the Mormon Temple and Tabernacle. The temple is a handsome gray granite building which, with its graceful towers, dominates the view in this part of the city. Photograph by Shiplers, Salt Lake City.

A. SEA GULL MONUMENT, SALT LAKE CITY.

A monument to commemorate the destruction by sea gulls of the hordes of crickets which, in 1848, threatened the crops and indirectly the lives of the pioneers in the Salt Lake valley. Their intervention is regarded by the Mormon people as due to Divine Providence, and this beautiful column is intended to express their gratitude. Photograph by the Utah Photo. Materials Co.

B. BATHING IN GREAT SALT LAKE.

The opportunity to bathe in the heavy waters of Great Salt Lake attracts many travelers. The lake is so shallow that the bather may go far out without getting beyond his depth, and even when he is in deep water the amount of salt in the water is so great that sinking is almost impossible. Photograph furnished by the Denver & Rio Grande Western Railroad.

them into ditches and upon piles of burning reeds, striving in every way to stop the flood of destruction, but all in vain. The people then became greatly alarmed lest their whole crop should be destroyed and they should be left to starve, so a day of fasting and prayer was appointed, as the people had great confidence in the power and willingness of God to help the faithful.

The result has been regarded by all the people of Utah as a miracle and as a direct answer to their supplications. From the shores and islands of Great Salt Lake came myriads upon myriads of gulls until the sky seemed dark with their wings and the air seemed to pulsate with their wild cries. The people were fearful that a new enemy of destruction was upon them until they saw the gulls alight on the fields and begin to devour the crickets. As the gulls came by thousands it was but a short time until the fields were cleared of the pest, and then the gulls wheeled into the air and departed for their island homes. It is no wonder that the people look upon the advent of the birds as a direct answer to their appeal to God and that even to-day the gulls are regarded as the great protectors of the Mormon people.

The gull has been selected as the emblem of the State, and the monument recently erected in Temple Square (Pl. XCIV, *A*) is intended to express the gratitude which the Mormon people feel for the deliverance from the disaster that threatened the early settlers. The gull also appears on the main piece in the handsome silver service given by the State to the battleship *Utah*.

Temple Square is the center of the Mormon stronghold in the city, for around it are clustered many buildings of historic interest and also those used by the church at the present time. These buildings include the new Utah Hotel, built by the church, the church tithing house, Lion House, Beehive House (the home of Brigham Young and his many wives), Amelia Palace, and Eagle Gate, erected by Brigham Young (Pl. XCII, *B*). Across the street is the great Zion Cooperative Mercantile Institution or Z. C. M. I., as it is familiarly called. The Deseret News, founded in 1851, occupies the other corner, and many other buildings belonging to the church are scattered throughout the city. There are also fine clubhouses, a public library, and numerous skyscrapers and manufacturing plants.

The city derives its water supply from the many canyons that seam the front of the Wasatch Mountains. The first of these streams to be utilized was City Creek, which cuts through the terrace east of the new Capitol Building. City Canyon has been made into one of the most charming parks in the country, so that it serves the double purpose of keeping the water supply uncontaminated

and providing an outing place for the people. The streams in the other canyons have been requisitioned by the city, and now much of the water comes from Big Cottonwood Canyon, more than 20 miles to the south.

The city is noted for its fine shade trees and for the beautiful velvety lawns which abound almost everywhere, especially around the public buildings and the handsome residences on Brigham Street. There are some warm sulphur springs and bathhouses at the foot of the terrace in the northwestern quarter of the city.

ONE-DAY TRIPS BY RAIL FROM SALT LAKE CITY.

A few one-day trips may be made by rail from Salt Lake City, either for pleasure, for seeing the surrounding country, or for studying some of the larger mines or mining districts.

SALTAIR BATHING BEACH.

As Great Salt Lake is the one natural feature which can not be duplicated in any other part of the country, people are naturally curious to see it and to have a chance to bathe in its waters. Many are familiar with the salt water of the ocean, but a large lake containing salt water is to most people a novelty. As the shores of Great Salt Lake are 10 miles from the city, the trip is generally made by rail. A large and ornate pavilion, called Saltair, has been built at the water's edge, and the traveler may enjoy bathing in the salt water or dancing in the pavilion. The facilities for dancing are not out of the ordinary, but the bathing, on account of the high mineral content of the water and its consequent density, is peculiar. Only with difficulty can the bather keep his feet from rising to the surface, and if he balances himself in an upright position only the lower part of the body is in the water and the head and shoulders rise above it. On account of the heaviness of the water the traveler may be interested in knowing something of the history of Great Salt Lake, as it is known to geologists, and the reason for its intense saltiness.[84]

[84] The following description of Great Salt Lake was written by G. K. Gilbert, who made an exhaustive study of the subject:

"Great Salt Lake has no outlet. Jordan River, which enters it from the south, is the outlet of Utah Lake. Bear River, coming from the north, carries the outflow from Bear Lake. The waters of Utah and Bear lakes and of Jordan and Bear rivers are fresh, and so is the water of Weber River, the third great tributary of Great Salt Lake, but the lake into which the three rivers flow is saline. It is saline because it has no outlet. The fresh waters of the rivers contain some saline matter, but the quantity is too small to be discovered by taste. As stated by the chemist, in parts per million, the quantity seems minute, but when account is taken also of the total volume of water brought by the streams to the lake in a year their burden of saline

GEOLOGIC AND TOPOGRAPHIC MAP
OF THE
RIO GRANDE ROUTE
From Denver, Colorado, to Salt Lake City, Utah

Compiled from United States Geological Survey atlas sheets and reports, from railroad alinements and profiles supplied by the Denver & Rio Grande Western Railroad Co., and from additional information collected with the assistance of that company

PREPARED UNDER THE DIRECTION OF
GEORGE OTIS SMITH, DIRECTOR

DAVID WHITE, Chief Geologist
M. R. CAMPBELL, Geologist
C. H. BIRDSEYE, Chief Topographic Engineer
A. C. ROBERTS, Topographer

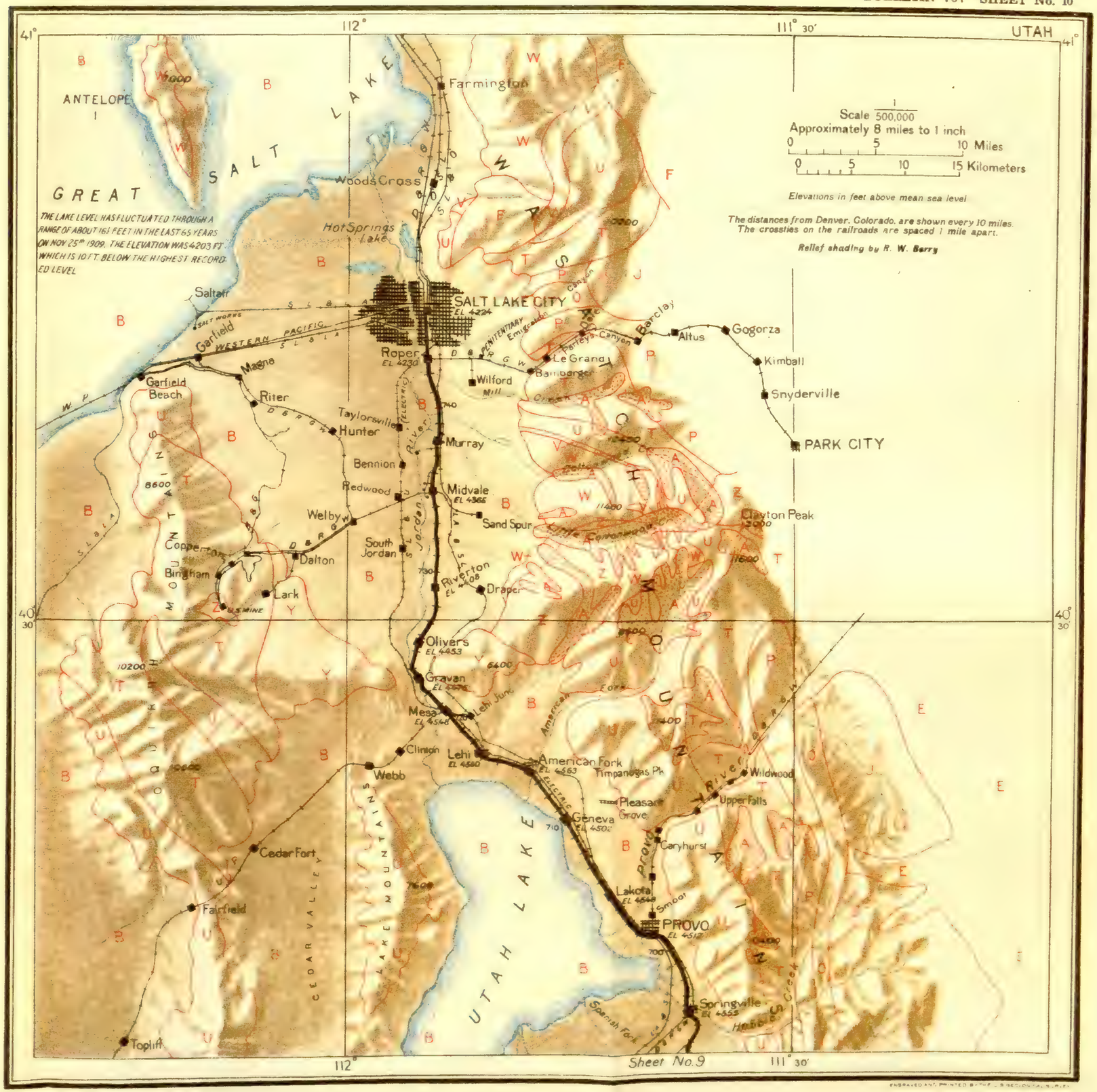
1922

EXPLANATION

		Age	Thickness in feet
A	Mountain glaciers as they were during the Great Ice Age	Pleistocene	
B	Lake Bonneville at its highest stage and the sediments deposited in its waters	Pleistocene	
E	White shale and sandstone (Green River formation)	Tertiary (*Eocene*)	
F	Red shale, sandstone, and conglomerate (Wasatch formation)	Tertiary (*Eocene*)	
J	Shale and sandstone (Mancos shale)	Upper Cretaceous	
O	Limestone and sandstone	Jurassic	
P	Bright-red shale and sandstone	Triassic	
T	Red sandstone and conglomerate (Park City formation) (Weber quartzite)	Carboniferous (*Permian and Pennsylvanian*)	9,000
U	Limestone	Carboniferous (*Mississippian*) Devonian Cambrian	7,000
V	Shale and quartzite	Cambrian	2,000
W	Quartzite, schist, and slate	Pre-Cambrian	12,000
Y	Lava flows (andesite)	Tertiary	
Z	Igneous intrusive rocks (granite, diorite, and porphyry)		

Fault

The geology of the region about Salt Lake City is very complicated, and it has not been mapped in detail except in the mining districts. The map here given is based largely on that of the Fortieth Parallel Survey, modified to fit, as well as possible, the present work



PARLEYS CANYON AND PARK CITY.

An interesting trip from Salt Lake City is that by way of the Denver & Rio Grande Western Railroad through Parleys Canyon to Park City. This trip has much of interest to almost every traveler, for the route follows for a distance the old Mormon trail by which many of the immigrants reached Salt Lake City, thus giving it a historic interest, and it ends at the mining town of Park City, one of the great gold, silver, and lead camps in the State.

The route lies south along the main line of the railroad to Roper, a distance of 2½ miles from the station at Salt Lake City. Here the road turns to the east (left) and pursues a nearly direct course to

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matter is found to be really great, amounting annually to more than 500,000 tons. Year by year and century by century the water which they pour into the lake is evaporated, but the dissolved solids can not escape in that way and therefore remain. They have accumulated until the lake water is approximately saturated, holding nearly as much mineral matter as it can retain in solution. The lake contains over 5,000,000,000 tons of common salt and about 900,000,000 tons of Glauber's salt, or sodium sulphate, as well as other mineral matter.

"Another consequence of the lack of outlet is that the lake varies from time to time in size. Whenever the gain from inflow is greater than the loss from evaporation the level of the water surface rises; when the loss is greater it falls. Each year there is a rise, beginning in winter, when the cool air has little power to absorb moisture, and continuing through spring, when the rivers are swollen by the melting of snows in the mountains. Each year there is a fall, beginning in summer, when the hot air rapidly absorbs the water, and continuing in autumn, when the rivers are smallest. This annual oscillation amounts on the average to about 16 inches.

"In some years the rainfall and snowfall are greater than in others, and then the lake usually receives more water than it parts with, so that the surface is left higher than it was before. In a series of wet years the lake level progressively rises; in a series of dry years it progressively falls; and as the rainfall is irregular the fluctuations of the lake are conspicuous. Since definite knowledge of the lake began in 1850 there have been five periods of increase and four of decrease. (See fig. 62.) The summer levels of 1868 and 1877 were more than 10 feet above the summer level of 1850, and those of 1903 and 1905 were 4 feet

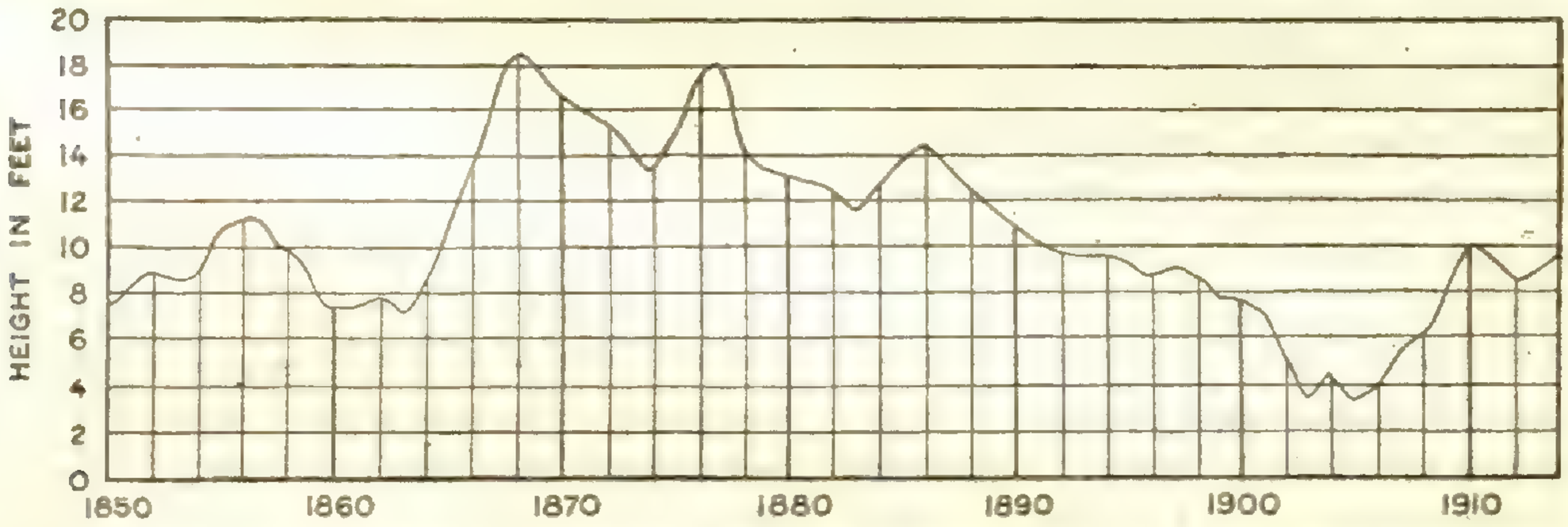

FIGURE 62.—Fluctuation in level of Great Salt Lake from 1850 to 1914, as determined by gage readings or computed from precipitation records.

the mouth of Parleys Canyon, so named in honor of Parley P. Pratt, the leader of the "First Immigration," or handcart companies. In crossing the valley the traveler may obtain a good idea of its productiveness, for here he sees all kinds of agricultural activities—truck gardening, fruit growing, and live-stock raising. The area passed through is largely suburban, with comfortable bungalows embowered in shade. Just beyond the station of Sugar House is the State penitentiary, on the left.

From time to time in passing across this low land the traveler can see the terraces back of the city, the State Capitol, the University of

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below that of 1850. The level of 1914 was 6 feet above that for 1905.

"The land bordering the lake has in many places a slope so gentle that a small change in the height of the water surface makes a great change in the area of the lake. On a map completed in 1850 the area shown is 1,750 square miles; on a map made in 1869 it is 2,170 square miles. In the interval between the two surveys the lake had risen 10 feet and this rise enlarged the area about 24 per cent. From the greater surface the evaporation was of course greater, and the dependence of evaporation on area is thus an important factor in regulating the size of the lake. The effect of a long series of wet years is somewhat reduced by the resulting increase of evaporation surface, and the effect of a series of dry years is lessened by the resulting reduction of surface exposed to evaporation. This natural and automatic control limits the range of oscillation and gives a certain permanence to what may be called a normal or average level. A change in the normal can occur only when some new factor is introduced.

"Both man and nature have introduced new factors and thus have produced changes in the normal level. The occupation of the surrounding region by white men has recently modified the face of the land in ways that have a recognized influence on the water level; and the ancient history of the lake includes enormous modifications in response to changes of climate.

"Of human influences the most telling has arisen from the development of agriculture with irrigation. In irrigation the water of rivers and creeks is diverted to cultivated fields, which first absorb it and then through evaporation feed it to the air; and the water thus consumed by utilization is lost to the lake. With the gradual enlargement of the irrigated area the normal level of the lake is inevitably being lowered, and engineers are already confident that the high-water mark of 1877 will never again be reached. On the other hand, there is no reason to expect the lake's extinction, for there is a limit to the possibilities of irrigation.

"The fresh water brought by the rivers mingles gradually with the brine, and as the river mouths are on or near the eastern shore the brine is not so strong at the east as at the west. Analyses of samples of the brine gathered at different points and in different years report the dissolved solids as from 13.7 to 27.7 per cent by weight. A sample taken in August, 1914, contained 18.9 per cent of solids. At the present time the average salinity of the lake is about 5½ times that of the ocean, and its density is 14.5 per cent greater than that of fresh water. * * *

"The brine is weakest in the northeastern arm. * * * This arm has been partitioned from the main body

Utah, and Fort Douglas. Parleys Canyon is the second one south of the fort and the next one south of Emigration Canyon.

The canyon is narrow and somewhat winding and in its lower part is rather rugged and rocky. The red sandstone and quartzite which form so conspicuous a feature of the Wasatch Range show on the left, but in a short distance they are cut through by the canyon, and then they make the great mountain slope on the right. The rock is resistant to weathering and stands out in great cliffs and ribs of red that cross the slope nearly at right angles. Farther up, the

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by the embankment of the Southern Pacific Co. and is continuously supplied with fresh water by Bear River. Ice can form on the stronger brine only in zero weather, but this arm is frozen from side to side every winter, and sleighs have been driven across it.

"The only climatic element with which the lake oscillations have been connected by direct observation is precipitation—the lake rises or sinks as the fall of rain and snow is great or small—but it is easy to understand that the balance between supply and loss of water may also be disturbed by any change of climate which affects the rate of evaporation. As every laundress well knows, evaporation is favored by heat, by dryness of the air, and by strength of wind and is retarded by cold, by moisture in the air, and by calm. So there are at least four ways in which changes of climate may cause the lake to expand or contract. * * *

"The only permanent animal inhabitant of Great Salt Lake is a tiny 'brine shrimp,' a third of an inch in length. A more conspicuous temporary resident is a minute fly, which passes its larval stage in the water and when its transformation takes place leaves behind it the discarded skin. These flies are so numerous in their season that even the passing tourist should feel grateful that they do not bite. Their brown exuviae darken the water edge and often sully broad belts of the lake surface. More decorative denizens are gulls and pelicans, which find safe nesting ground on some of the smaller islands. There are no shoal-water plants, and the salt spray of the beach is fatal to all land vegetation along the shores.

"When the lake is low its salt is segregated and deposited in shallow lagoons at its margin, to be redissolved when the water rises. Each autumn, as the water cools, deposits of hydrated sodium sulphate (Glauber's salt) coat piles and other fixed objects near the water surface, and the deposits increase as the temperature falls. * * * Calcium carbonate—the mineral constituting limestone, travertine, and chalk—is continuously and permanently separated from the water, which is unable to retain that which is brought to it by the rivers. Along the shores it forms minute balls, which together constitute sand, a sand quite distinct from the siliceous sand of ordinary beaches.

"Man makes little use of the lake. On its shores there are neither fisheries nor ports, and commerce finds it an impediment rather than an aid. Its deposits of Glauber's salts, which it offers for the gathering, are neglected because the world's demand is small and is cheaply met in other ways. Its common salt is harvested with great economy of effort, for impurities are easily excluded, and the work of evaporation is performed by the sun. The present annual output of 40,000 tons must be multiplied fivefold before it can commence to weaken the brine. For the rest, man is content to resort to its shore for bathing and to realize a new sensation as he floats upon its surface."

canyon is cut entirely in gray limestone and calcareous shale, and here the slopes are generally smooth and the canyon, though V-shaped, has not particularly steep walls. The canyon continues to widen and the surrounding hills to diminish in height until about a mile above the station of Dale the valley is very broad and shallow.

Here the creek forks and the railroad follows the south fork to its head. If the traveler will observe closely the slope north of the stream at the point where it divides he will see an old road winding up over the low ridge which separates it from Emigration Canyon. This road is the old Mormon trail. It crossed the high mountain that may be seen on the left, came down the north fork of the creek, and then crossed the divide to Emigration Canyon, in which it may still be seen at the point where it comes down to the creek. As the traveler who makes the journey from Salt Lake City to Park City has an opportunity to see some of the country crossed by the Mormon pioneers a more extended description of the route they followed and the reasons for so doing are given in the following footnote. [85]

[85] Although it is probable that between the years 1825 and 1840 most of the streams, valleys, and passes of the region about Great Salt Lake had been traversed by hunters and trappers in search of the beaver, these dauntless explorers left few if any records of their explorations, and the credit for the discovery of new routes and the making of new trails must be given to those who first gave to the world a written description of their travels. This is undoubtedly true of the route that the Mormons followed down Emigration Canyon. It is probable, indeed almost certain, that Jim Bridger was familiar with every valley and canyon and mountain pass in this region long before the advent of the Mormon pioneers, but the information was never published, and it was circulated only from one trapper to another by word of mouth.

The main route through this western country until 1846 was the Oregon Trail, which crossed southern Wyoming to Jim Bridger's fort, near the southwestern corner of the State, and then turned sharply to the north and passed through Idaho. Emigrants to Oregon and California traveled together by the usual route up Platte River, along the Sweetwater, and through South Pass to Fort Bridger and then to Bear River valley. They followed this stream as far as the soda springs, where those for Oregon turned north to Fort Hall, and those for California followed Bear River southward, until at a point within 10 miles of Great Salt Lake they turned to the west to Ogden (Humboldt) River. (See fig. 63.)

The route thus described was followed until 1846, when the emigrants destined for California were met in the region of Fort Bridger, which previously had been abandoned, by Lansford W. Hastings and James M. Hudspeth, guides, who induced the emigrants to try shorter routes than that by the soda springs. One of the parties, which was guided part of the way by Hudspeth and equipped with pack mules, followed down Echo Canyon and Weber River along the present route of the Union Pacific Railroad to Great Salt Lake. This party had little difficulty and was one of the first of the season to reach California. Two parties guided by Hastings had much difficulty in finding a

The railroad climbs steadily and makes several loops in order to decrease the grade and finally arrives at the summit at the siding of Altus (6,900 feet), about 2,700 feet above the starting point at Salt Lake City. By several loops and curves it descends on the east to East Canyon Creek at Gogorza and then follows up that stream

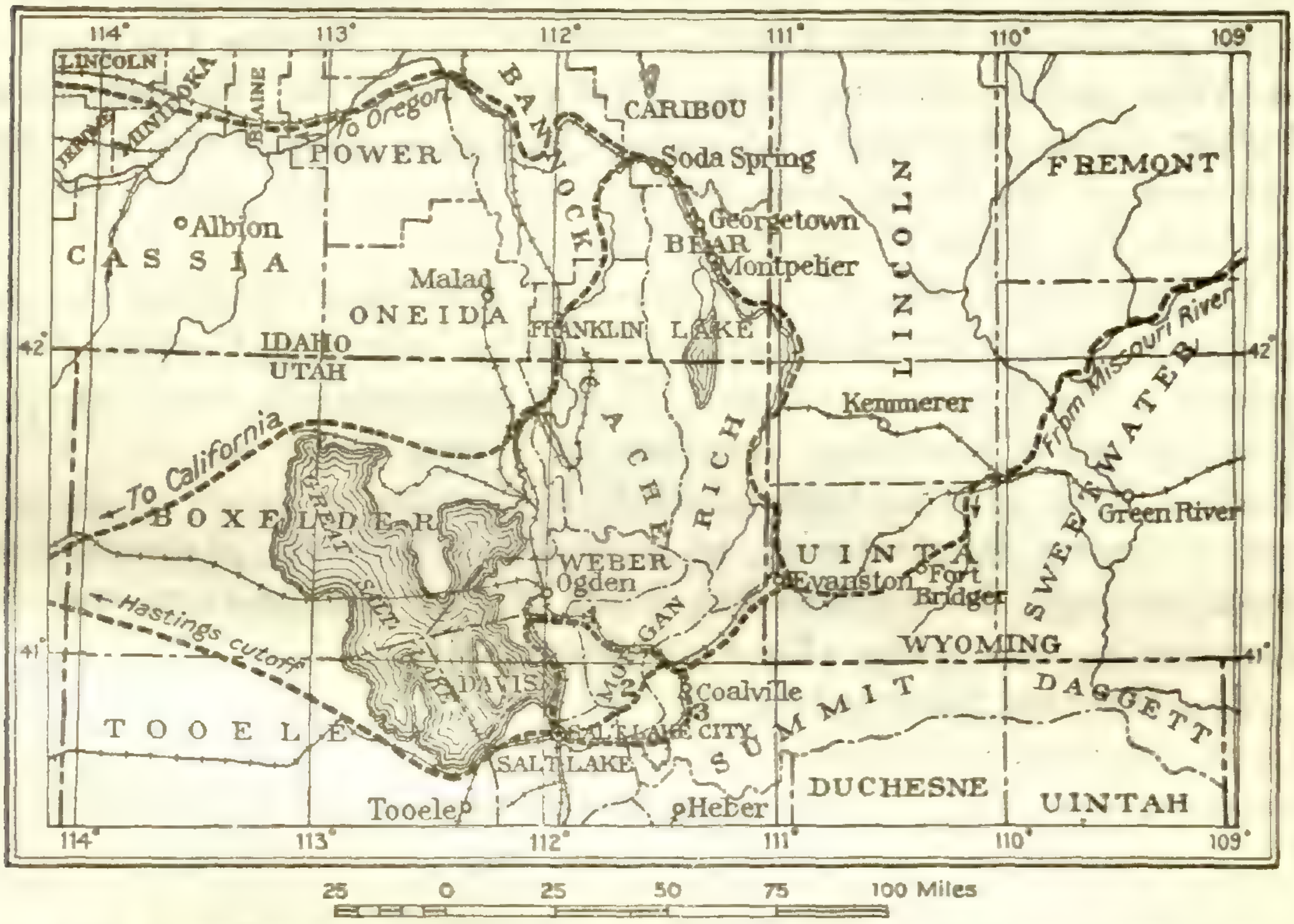

FIGURE 63.—Map showing old trails for Oregon and California. 1, Weber Canyon route; 2, East Canyon route; 3, Parleys Park route.

to Kimball. Although the original trail by which Brigham Young and his party of pioneers entered the valley of Great Salt Lake came up East Canyon Creek and crossed the crest of the mountains north of Altus at nearly its highest point, this trail was used only a short

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way for their wagons through Weber Canyon and were so much delayed that they were the last to cross the Sierra Nevada that season. On account of the difficulty experienced in Weber Canyon, Hastings advised some of the parties following to take a route farther south, passing around the south end of Great Salt Lake. This was partly explored the previous year by Frémont and later became known as the "Hastings cut-off."

The ill-fated Donner party, which left Fort Bridger on July 28, 1846, were undecided which route to take. As they were only a few days behind Hastings a messenger was sent ahead to confer with him. He advised the "cut-off," and as a result the party proceeded down Weber River only to the head of the dreaded canyon, 6 miles below the mouth of Echo Canyon, at a point where the station of Henefer is now situated on the Union Pacific Railroad. Here they turned to the left and crossed over a divide and down a ravine to what is now known as East Canyon Creek, a route probably as rugged as the one they were trying to avoid. They followed this stream up for a distance of about 8 miles through a very rocky

time, for three years later the incoming bands of Mormons, instead of following Weber River downstream from the mouth of Echo Canyon, turned up Weber River and were soon in the open valley where Coalville now stands. They continued up the Weber to Wanship, where they turned to the west, and after crossing a low, flat divide reached Parleys Park at Kimball. From this point their route practically followed that of the railroad, crossing the summit at Altus and continuing down Parleys Canyon to the Salt Lake Valley. Over this trail came the "handcart companies" of 1856 and most of the Mormon emigrants who entered the valley prior to the building of the Union Pacific Railroad.

The Denver & Rio Grande Western Railroad continues to the southeast from Kimball through a wide flat known as Parleys Park, crosses a divide so low that it is all but imperceptible, and then follows up one of the head branches of Weber River to Park City. Parleys Park is at so high an altitude that the ordinary crops can not be grown satisfactorily, so it is devoted almost exclusively to stock raising. It contains fine fields of hay and pasture, and the surrounding mountains afford ample range.

The Wasatch Mountains are noted for the brilliancy of their autumn coloring, and should the traveler pass this way in the early autumn, after the first week in September, he will doubtless see a

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canyon and then turned to the right and ascended a tributary stream which heads in one of the high summits of the Wasatch Range. They crossed this summit and descended the northern branch of what is now known as Parleys Canyon. This they followed until the canyon closed in about them and then they crossed the low ridge on the right into what is now called Emigration Canyon, and this they descended to the main valley. The road was so rough and mountainous that it took them 16 days to travel from Fort Bridger to the valley of Great Salt Lake. This delay and the difficulty which the party experienced in the desert around the south end of Great Salt Lake caused them to be overtaken by winter in the Sierra Nevada, and here the whole party would have perished had they not been rescued by men sent out from the mining camps of California. At any rate, 39 of the 87 persons in the party died of cold and starvation.

Many have wondered why the Mormon pioneers followed this route instead of keeping down Weber Canyon and reaching the valley at Ogden. It seems almost certain that they had, while at Fort Bridger, determined upon their future location, provided the soil was found to be suitable for agriculture. As the location was practically decided upon it was only natural for them to take the most direct route, which was evidently the so-called Hastings cut-off, or the Emigration Canyon trail, as it was known in after years. Besides, they knew that the trail was passable, for the Donner party had cleared it out the year before. A glance at the map will show that the Mormon trail is a much more direct route from Fort Bridger to Salt Lake City than the route through Echo and Weber canyons by way of Ogden. Some of the old trail is still visible in Emigration Canyon, which is one of the points of interest about Salt Lake City.

riot of color on the mountain sides, the dwarf maples showing great streaks and splotches of the most vivid scarlet and the aspens rivaling them with a blaze of yellow.

The ores mined at Park City carry silver, gold, lead, zinc, and copper. At the end of 1920 the camp had produced 142,490,000 ounces of silver, gold valued at $4,603,000, 661,000 tons of lead, 37,000 tons of zinc, and 17,000 tons of copper. This was marketed for over $183,800,000. The ore occurs as vein fillings or in bedded layers in the sandstone and limestone of the Carboniferous system.

BINGHAM, THE GREAT COPPER CAMP.

A visit to Bingham can hardly fail to interest the traveler, for almost everyone enjoys seeing the wonderful things man is accomplishing, even though he may not be interested in them financially or professionally, and nothing more spectacular than the mining in Bingham Gulch can be imagined. In a visit to most mining districts the traveler actually sees little of real interest. He may be told that this or that mine has produced so many millions of dollars, but great dump heaps and mine buildings are about all he sees, and he generally leaves the camp with a very hazy idea of what actually takes place in the mine, for he can not see the work that is being done; but in Bingham it is different. Here he can see the work actually in progress, and he can almost watch the movement of the ore from the time it is gathered up by the giant steam shovels until it is delivered to the smelter. It is a wonderful sight that can be rivaled only at some of the great iron-ore mines of Minnesota.

In order to reach Bingham the traveler has the choice of three routes: He may go by train on the Denver & Rio Grande Western Railroad or the Los Angeles & Salt Lake Railroad, or he may go by automobile stage or private conveyance. As the camp should be approached by the route that will give the best view with the least effort, for the sake of first impressions, the writer would recommend that the traveler take the Los Angeles & Salt Lake route, and then he may return if he wishes by any other of the routes mentioned.

In going to Bingham by way of the Los Angeles & Salt Lake Railroad the traveler goes to Garfield on the main line toward Los Angeles. In this part of his journey he has a good opportunity to see the great flat plain at about the level of the lake, which stretches from Salt Lake City to Garfield, a distance of 15 miles. Near Garfield he may see on the north (right) the pavilion at Saltair and some of the salt-manufacturing plants in the vicinity, but they are so far away that he may not be able to distinguish details. He sees little or nothing of the lake, for it is far to the north. The town of Garfield was built to accommodate the workers in the Gar-

field smelter, which was put in operation in 1906. The smelter is not visible from the train, but the high stack rises from behind the sharp point of rocks on the right as the train makes the curve into Garfield. As few travelers are familiar with the smelting of ores, a brief description of the work carried on in the Garfield smelter, as well as in those seen at other places along the railroad, is given by C. N. Gerry in the footnote.[86]

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[86] "A smelter is an establishment where ores are reduced to the metallic state or to matte (pronounced mat; crude metal containing sulphur, which needs further purification) by melting in a furnace. This statement is simple, but the actual working out of the process is often lengthy and complex. There are many kinds of smelters—iron, zinc, copper, and lead smelters in the East and principally copper and lead smelters in the West. Some plants are equipped for smelting both lead and copper and for producing at the same time gold and silver and perhaps the rarer metals in the base bullion. The smelter at Garfield, Utah, produces blister copper (crude pig copper, so called from gas blisters that form on the surface while cooling), from which gold, silver, and copper are afterward refined. The dust from the furnaces is also saved, and from it are obtained gold, silver, and lead. The smelter at Murray produces principally lead bullion containing a small percentage of silver and gold, a matte containing copper as well as the precious metals, and arsenic from the flue dust. At the Midvale smelter the products are much the same as those of the Murray smelter, but in addition the metal cadmium is obtained. Some smelters operate concentration mills in conjunction with the furnaces, in order to make a higher grade of ore by rejecting a part that is worthless or to separate one kind of ore from another.

In the early days some of the mines were equipped with small furnaces, but as these were generally crude the losses in slag and fumes were great. Mine smelters have been generally abandoned, and now it is more economical and convenient to ship the ore to a centrally located custom plant, where it is smelted with ores from other mines or even other districts. The ore when received is usually crushed and carefully mixed, and a small sample is taken that will represent the entire lot. This sample is "assayed" both by the mining company and the smelting company. That is, it is tested to ascertain how much of each of the metals it contains. The assay at the smelter is often watched by representatives of the mining companies called "moochers." If the assays of the owner and of the smelter do not agree closely an umpire assayer is called upon to analyze a third sample, and the differences are adjusted by arbitration. The ore is then paid for according to current metal prices less fixed deductions for losses in the process, penalties for objectionable ingredients, and a definite charge for smelting—all these items being frequently covered by contract. The ores that reach a custom smelter differ greatly in their composition; some contain lead or copper as sulphides with gold and silver; others are oxides or carbonates that have lost the sulphur. Pyritic or iron sulphide ores often contain gold and silver, and a familiar ore is one that contains much silica or quartz with gold and silver. The western sulphide ores frequently contain much zinc, which is objectionable in lead smelting and is ordinarily penalized by the smelters when above a certain percentage. If the ore contains much sulphur, as it commonly does, it receives a preliminary treatment in roasters. Some of these roast-

From Garfield the route lies almost south along the eastern foot of the Oquirrh Range. At Arthur and Magna there are large mills for crushing and concentrating the copper ores of the Bingham district. The Magna plant (see Pl. XCVI, *A*) has a capacity of 14,000 tons daily of low-grade ore, and the Arthur plant of 10,000 tons. From Magna southward the train runs over the tracks of the Bingham & Garfield Railway, which was built in 1911 for the sole purpose of transporting ore from Bingham to Garfield. This road is said to handle a greater tonnage of freight to the mile than any other railroad in the United States.

After leaving Magna the track winds up the slopes of the mountain, but as it traverses mainly the sand and gravel deposited in ancient Lake Bonneville, there are few rock cuts. In this interval the traveler has several excellent views of the terraces of Lake Bonneville (see Pl. XCVI, *B*), and as the track enters the mouth of Bingham Canyon the road has attained about the level of the highest or Bonneville shore line.

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ers are circular, about 22 feet in diameter, and have a number of hearths on which the ore is slowly "rabbled" or raked by arms that extend from the center. After entering at the top and passing over the hearths it has been relieved of most of its sulphur and is then dumped into cars. Another type of roaster produces a coherent mass called sinter, which naturally makes a less dusty charge for the blast furnace. In some places a series of pots are used in which the sulphur is burned off by the aid of a blast after the introduction of burning coal. Years ago at Butte, Mont., the ore was roasted in the open air on piles of cordwood, but the farmers objected to a process which permitted the escaping gases to destroy vegetation. In most places, therefore, the smoke and gases are now carefully diverted and treated. The result is that farms now thrive close to smelter stacks, and the smelters make a much better saving of metal.

The blast furnace in common use is upright and has a rectangular cross section. It is cooled by a water jacket, and the charge on the hearth receives an air blast, as its name implies. For the best results the charge must be carefully calculated and weighed. It usually consists of about 75 per cent of ore that has been previously roasted, mixed with coke, limestone, and old scrap iron or slag. After smelting has been in progress several hours lead bullion forms in the crucible, if the charge consisted of lead ores, and slag and matte flow into special cars. The bullion is skimmed to remove the dross or impurities and then cast into bars, which are shipped to refineries where the gold, silver, and lead are separated. The slag, which contains iron, silica, and other substances, is discarded, and the matte, which contains gold, silver, copper, and lead, is either crushed and returned to the blast furnace or shipped to a refinery. Some plants use reverbatory furnaces in smelting lead ores that contain little silica. These furnaces are horizontal and combine roasting with reduction. The product is lead bullion and a residue which may be treated in a blast furnace. In all these operations, but especially in the operation of the blast furnace, the draft of air takes up small particles of ore, and the intense heat volatilizes

By climbing steadily from Garfield the railroad is here about 200 feet above the bottom of the canyon, and the traveler may look down on the left and note all the activities of a mining town. (See Pl. XCV, *A*.) The canyon is very narrow, and the town consists of a single street with scarcely room enough for houses on both sides. The view from the train would be fine were it not that the road is chiefly carved through the mountains. From time to time the train emerges from the portal of a tunnel and crosses one of the side canyons on a steel trestle 200 feet or more high. The traveler may then have a good view of the canyon, but the mines are mostly above the town, so that they are not visible until the train stops.

When the traveler alights from the train he finds himself high up on the side of the canyon and at its largest fork. He may well stop here to look at the surroundings, for it is doubtful if he will find as good a viewpoint without considerable climbing. He may look in vain for the mines, but instead he will see the wall of the canyon before him creased with horizontal benches and on each of these benches an enormous steam shovel lifting the ore and its overburden

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some of the metals, such as lead, zinc, and arsenic. The fumes are therefore turned down into long semicircular flues, where the dust particles collect, or they are cooled and condensed to solids in chambers. In some plants the particles are collected by being passed through pipes fitted with a central insulated wire, the pipe and wire forming the two poles of a high-tension electric field. The dust becomes charged with electrostatic energy and is driven to one pole of the field, where it accumulates and is periodically collected. Arsenic is also saved by passing the fumes through thousands of woolen bags treated with zinc oxide or lime. At present many plants use the fumes in the manufacture of sulphuric acid, which is again utilized in the leaching of copper ores. These devices have brought a great change in smelting. Many years ago a dense volume of smoke marked the position of the smelter stack, but now the smoke nuisance is largely abated.

Copper smelting to a certain extent is similar to lead smelting, but the products must be treated somewhat differently. Roasters, reverberatories, and blast furnaces are used, but the operation of the blast furnace, instead of making copper bullion, results in copper matte, a product that contains copper, sulphur, and iron. This matte is again treated in converters which have an opening in the top to dispose of the fumes and to receive the matte when the converter is charged. An intense blast of air is forced in from the sides, allowing oxygen to combine with the sulphur and form sulphurous gases which are led away from the top, and after about 2 hours the matte is "blown" into the product known as blister copper, which contains about 98 per cent of pure copper. If much gold and silver is present the blister copper is further refined.

A large copper smelter in operation is a most impressive sight. It consists of a row of blast furnaces belching forth white-hot slag. Strings of cars take the fiery material to the slag dump, and glowing streams of the melted matte flow from the furnaces into large kettles. Traveling cranes pick up the kettles and pour the molten matte into the converters, where, with an intense light, the work of "blowing" begins, which changes the matte to blister copper.

A. BINGHAM CANYON.

View of the canyon above the mouth of Carrs Fork from the station of the Los Angeles & Salt Lake Railroad. The copper ore is mined by steam shovels and loaded directly into railroad cars, which are run on all the levels. It is then taken to the mills for concentration, and the concentrate goes to Garfield for smelting. Photograph by Shiplers, Salt Lake City.

B. BINGHAM MINE OF UTAH COPPER CO.

Near view of the copper mine, showing most of the 24 levels upon which excavating work is going on. The levels extend from the bottom to the top of the canyon wall, a vertical distance of about 1,600 feet. About 21,000 tons of material is handled daily in this mine. Photograph by Shiplers, Salt Lake City.

A. MAGNA MILL OF THE UTAH COPPER CO.

The Magna mill, at the north end of the Oquirrh Mountains, was built to concentrate a part of the copper ore mined at Bingham. It treats more than 10,000 tons of ore daily. Above the mill may be seen some of the terraces of old Lake Bonneville; the uppermost is the Bonneville shore line. Photograph by Shiplers, Salt Lake City.

B. BONNEVILLE SHORE LINE ON WASATCH MOUNTAINS.

Near view of the west face of the Wasatch Mountains showing the horizontal band across the mountain front that looks like a well-graded road. This is the beach cut by the waves of Lake Bonneville when it stood 1,000 feet higher than the water stands to-day in Great Salt Lake. Photograph by Shiplers, Salt Lake City.

upon waiting cars.[87] (See Pl. XCV, *B*.) When the cars are full they are drawn away and made up into trains to be sent to the concentrators at Magna and Arthur. The side of the canyon in front of the traveler is 1,600 feet high, and it is divided into 24 steam-shovel levels, on each of which is a railroad track. At present about 60,000

[87] C. N. Gerry gives the following account of the development of the mines at Bingham and the wonderful work that is now being done there.

About 25 miles southwest of Salt Lake City, in a narrow canyon, is the town of Bingham, which has been a mining center since 1865. Recently the camp has assumed great importance, and at the present time it is unique among producing regions in that it has the largest single copper mine in the United States. Up to 1900 the camp had been producing metals valued at more than a million dollars a year, and that was regarded as a large output. The production jumped to $3,000.000 in 1901, to $39,000,000 in 1915, and to $72,000,000 in 1917. In 1918 it fell to $62,800,000, in 1919 to $27,900,000, and in 1920 to $27,500,000. As a spot of beauty or a model of cleanliness the place is not worth noting, but its gigantic mining operations are certainly impressive.

The history of the first mineral discovery is unusual, for ore was found in 1863 by soldier prospectors under Gen. P. E. Connor, who was stationed at Fort Douglas. While the Indians were quietly hunting and the Mormons were peacefully pursuing agriculture and irrigation, the soldiers, who were from California, were engaged in the search for mineral wealth.

Although the district was never famous as a source of free gold, considerable placer mining was done about 1865 in the vicinity of the present town of Bingham and for several miles east along the canyon. The first shipment of copper ore, which was made in 1868, was hauled to a station on the Union Pacific Railroad and was shipped to Baltimore. Not until 1873 did railroad connection with the outside world give an impetus to genuine development. About this time the adverse attitude of the Mormons changed, and the church began to encourage the mining industry. Then followed a period of lead mining, which was fairly successful while the oxidized zone was being exploited. In the early eighties several stamp mills were erected to treat oxidized gold ore. Then other lead carbonate bodies containing silver were successfully mined until the decline in the price of silver in 1893. This period was followed by the development of the heavy copper and iron sulphide ore, which is a conspicuous ore of the camp even at the present time. It contains about 30 per cent of iron, 30 per cent of sulphur, and a few per cent of copper. The problem of economically treating it was not solved until 1899, when efficient smelting plants were constructed. Most of these plants were built in the Salt Lake Valley east of Bingham. As the lead mines became deeper sulphide ore began to appear, which added other difficulties to be overcome. Some of this ore was sufficiently rich to be shipped at a profit, but much of it required concentration, so plants using crushers, rolls, jigs, and concentration tables were erected. Several times these plants, as well as dwellings, have met with disaster when a large boulder or even a derailed engine rolled down the steep hillside. When much zinc sulphide occurred with the lead the smelters imposed a penalty, but later, when the zinc was separated, it became a valuable product. Not until 1909, however, was the zinc product sold. At present the entire output of the district is shipped and concentrated, or separated, and smelted. So the camp has had a great variety of ores, from simple free-gold ore and oxidized cop-

tons of material is being handled daily, of which 38,000 tons is cap rock and 22,000 tons ore.

As seen from the station of the Bingham & Garfield Railway the canyon resembles a fairy scene. Here and there on the mountain side gnomes and dwarfs are digging their way along its front. Puffs of steam show the location of tiny steam shovels laboring away to

per and lead ores to difficult sulphides of iron, lead, copper, and zinc, even down to the famous low-grade disseminated ore containing specks of copper sulphide that constitutes the bulk of the copper ore mined at the present time.

The treatment of the ore has kept pace with discovery, gradually developing from the panning of placer gold and the amalgamation and cyanidation of gold and silver ores to the concentration and separation of copper, lead, and zinc ores. The smelting has grown from the old furnace that looked like a stove to a plant that covers hundreds of acres.

About 1900 events of real importance to Bingham's growth began to occur. In that year the output of gold, silver, copper, and lead had a value of over $1,500,000, and there was a general consolidation of mining property in order to effect economy in operation, and the building of large smelting plants to treat these ores began.

In 1902 the United States Smelting & Refining Co. constructed a plant at Midvale, east of Bingham, to treat 1,000 tons of copper ore a day, and later the company built a lead plant to treat 400 tons a day. At present this plant has developed into one that treats 1,500 tons a day, and the copper furnaces are idle. A copper plant was also erected in the Salt Lake Valley by the Bingham Copper & Gold Co., which owned large interests at Bingham. The Highland Boy mine developed so extensive a body of copper ore that a smelting plant was built near Murray. Both these plants operated for years but were afterward dismantled. Ore from the Yampa mine was treated in a copper plant in the canyon below the town. The American Smelting & Refining Co.'s lead plant at Murray, with eight blast furnaces, was erected in 1901; it had much to do with the exploitation of lead ores from Bingham. There have been several concentration mills close to the mines, such as the Utah, Apex, Bingham, New Haven, and custom mills, but a considerable proportion of the lead-zinc ore is now shipped to Midvale, where it is concentrated and separated into lead and zinc products.

The operation of these mines created a maze of underground workings, miles in extent. Without a map or guide traveling in the tunnels is dangerous. Some years ago a Mexican criminal, by his knowledge of the workings of the Apex mine, succeeded in eluding the sheriff who was pursuing him. How he got out and where he went is one of the mysteries of Bingham.

In 1905 the 21 mines in operation produced more than a million tons of ore, which was valued at nearly $10,000,000. As many of the mines are several miles from the railroad terminus, it was necessary to haul the ore by teams or to use transportation tunnels or aerial tramways. Several tramways lead down the canyon or over the crest of the range to the International smelter at Tooele (too-ell'y), which in October, 1916, was treating 1,200 tons of copper charge and 1,500 tons of lead charge daily.

Although the ores mentioned have played an important part in the past development of Bingham, they are now of less relative value, for the great work of to-day is the mining, concentrating, and smelting of copper ore, which averages about 1.5 per cent of

help tear down the mountain. Locomotives with long lines of ore cars shuttle back and forth across the face of the mountain, at times directly above the spectator, then again far below. It seems to be pandemonium let loose, but out of it comes the ore in a steady stream that makes the spectator wonder.

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metallic copper. This ore occurs as grains of copper sulphide disseminated in a large mass of monzonite.

From 1903 to 1909 the Boston Consolidated Mining Co., which operated on part of this ground, used steam shovels and produced over 43,000,000 pounds of copper. The ore averaged 1.65 per cent copper, or only 33 pounds of copper in 2,000 pounds of ore. The loss in milling reduced this figure to 23 pounds actually recovered.

In 1904 the Utah Copper Co. built the Copperton mill for experimental work in the lower canyon. As the work progressed the mill was increased in size until it could treat 900 tons of ore a day. At the same time underground development was proceeding, and in 1906 it amounted to nearly 18 miles. The plan was to extract ore by the caving system, but when some idea was gained of the extent of the ore body and the amount that would be required to make a sufficient tonnage of commercial concentrate, steam shovels were put to work. These shovels have been used ever since, partly to load ores on cars for milling and partly to remove the top or cap of the deposit, a brown oxidized material from which part of the copper has been removed by natural leaching. A photograph taken in 1906 shows only one steam shovel, and that one was at work on the capping. Trees still grew on the hillside, where apparently slight change had been made on the surface.

In 1909 the property of the Boston Co. was consolidated with that of the Utah Copper Co., which thus acquired 740 acres of mineralized territory, most of which is north and west of the main canyon. When the first mill at Copperton proved that the ore could be successfully treated the Magna mill (Pl. XCVI, *A*), 15 miles north of Bingham, was constructed, section by section, until its capacity was 4,000 tons of material a day. The ore was concentrated at the ratio of 20 tons of ore containing less than 2 per cent to 1 ton of concentrate containing about 25 per cent copper, leaving 95 per cent of the original material to be discarded as tailing. The development proceeded so rapidly that the company was reorganized many times. In 1904 it was capitalized at $4,500,000, and in 1910 its capitalization reached $25,000,000. To increase the extraction of ore the only thing necessary was more steam shovels. The solitary shovel of 1906 had 22 companions in 1910. But transportation and milling had to keep pace with mining. The Garfield branch of the Denver & Rio Grande Railroad hauled an immense tonnage, but in 1911 the Utah Copper Co. constructed a railroad from Bingham to Garfield, a distance of 20 miles, in order to meet its needs.

After the property of the Boston Consolidated Co. was taken over the 3,000-ton mill near Garfield was remodeled and enlarged. This mill was later called the Arthur plant. It treated 8,000 tons of ore a day in 1910 and 15,000 tons in 1918; the Magna mill treated 10,000 tons of ore a day in 1910 and 18,000 tons in 1918. The Magna plant was shut down in February, 1919. In 1920 the Arthur plant treated 5,500,000 tons of ore. A mill treating 500 tons is considered a fair-sized plant, but these mills require 12 trains a day hauling 40 cars of 50 tons of ore each. The Magna plant alone covers 20 acres, and the company owns an immense acreage for the disposal of the tailings. Like most

The town of Bingham may be as interesting to the traveler as the great mines that give it life. Through force of circumstances it is a one-street town, and this street winds and twists with the winding and twisting of the narrow canyon. The street is so narrow that the traffic is accommodated with difficulty. By patience teams and wagons are maneuvered so as to allow automobiles to pass, but even these autocrats of the highway are sometimes involved in an almost hopeless tangle. Residences have been built wherever there was space; if this space was on level ground so much the better, but it

plants of this character, it is built on a hillside so that the ore may pass by gravity from one process to another. The ore is ground very fine. After the material has been well classified it reaches tables and vanners. The table has a plane surface, which is tilted at an angle and partly covered with riffles or strips of wood. As the machine is agitated the water carries the lighter gangue or waste material over the edge, separating it from the heavier copper and iron minerals held by the riffles. A well-managed table will sometimes distinctly show three different minerals, such as lead, zinc, and iron sulphides, which have been separated because of their difference in weight. This machine applies the principle of wet concentration. The principle of flotation is the direct opposite of this principle, for the heavy metallic particles in the flotation process float on a froth after the finely crushed ore is mixed with oil and air. Experiments with flotation are going on at Magna and Arthur, and if this system is used in conjunction with wet concentration the saving from losses in tailing will probably be increased about 20 per cent. At present the mills save 63 per cent, or about 18 out of 28 pounds of copper. A ton of the ore treated would make a cube about 28 inches on a side, but the copper recovered would be only about a 4-inch cube. An additional 5 pounds to the ton amounts to a large increase in production if 8,000,000 tons are treated each year. If flotation can make a better saving on the sulphide ore and the leaching process can be used in treating the oxidized portion the future will be bright, especially as the company estimates the life of the mine at over 60 years. When copper is 25 cents a pound ore is worth over $4 a ton at the present rate of saving, and all costs of mining and treatment are less than $1.

The great work of mining may be observed from the station of the Bingham & Garfield Railroad. In the view looking south, as shown in Plate XCV, *B*, the Denver & Rio Grande Western tracks circle the hills on several levels. The northern side of the canyon is served by the Bingham & Garfield road. The work of the steam shovels can be seen to better advantage if one walks along the main canyon. The ore body is about a mile in length and approximately 1,500 feet above the level of the road. Over 43,000,000 tons has already been removed from the mine, and drilling in various parts of the area has shown that a total of 390,000,000 tons is available. Steam shovels (Pl. XCV, *B*) operate on a great many levels, from the base of the hill up to the very summit, where the cap is being removed and dumped near the old Jordan mine. In each scoopful the steam shovel lifts 4 tons of the ore into cars. The mining, handling, and concentrating on a large scale by the Utah Copper Co. of this great mass of low-grade ore, which for a long time was considered too poor to be of value, has revolutionized Bingham. The output of the Utah Copper Co. has grown rom 3,000,000 pounds of copper in 1903

was not left vacant even if it was on the steep mountain side. People live almost in the midst of the great excavation, and they soon become accustomed to the rumble of the train above, below, around, and in fact on all sides.

When the traveler has satisfied his curiosity regarding both the mine and the town he can return by way of the Denver & Rio Grande Western Railroad, which runs in the bottom of the canyon, to Salt Lake City to resume his westward journey, if he has not reached the end of his route.

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to a maximum of 206,000,000 pounds in 1917; in 1920 it was 106,600,000 pounds. The aggregate production for the district to the end of 1920 has been 2,100,000,000 pounds. In 1915 the gold and silver were about ten times, the lead twenty times, and the copper thirty times the output in 1900. Bingham should have celebrated its fiftieth anniversary in 1915, but the date was forgotten in the anxiety to add to a record of metal output valued at nearly $280,000,000 in 50 years. The total value at the end of 1920 was $538,000,000.

Several large low-grade deposits are worked in other States—at Ely, Nev.; Ray and Miami, Ariz.; and Chino, N. Mex.—but these do not compare in size or output with the mine of the Utah Copper Co. Credit for the great achievement must be given to many. Col. E. A. Wall always had implicit faith that this grade of mineral would eventually become commercial ore. The Boston Consolidated Co., with Mr. J. A. Bettles, worked out many of the mining and milling difficulties, and credit for organization and financing is due to Col. D. C. Jackling.

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